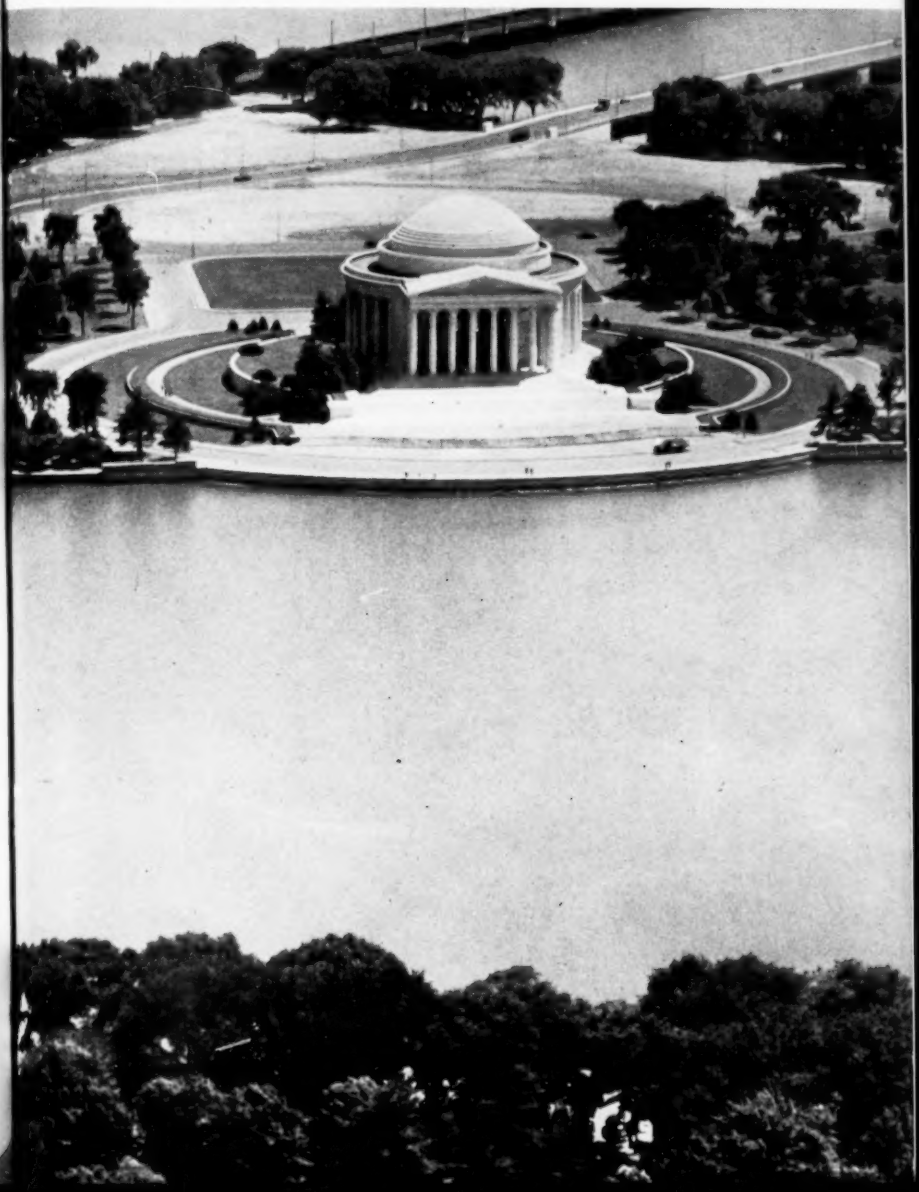
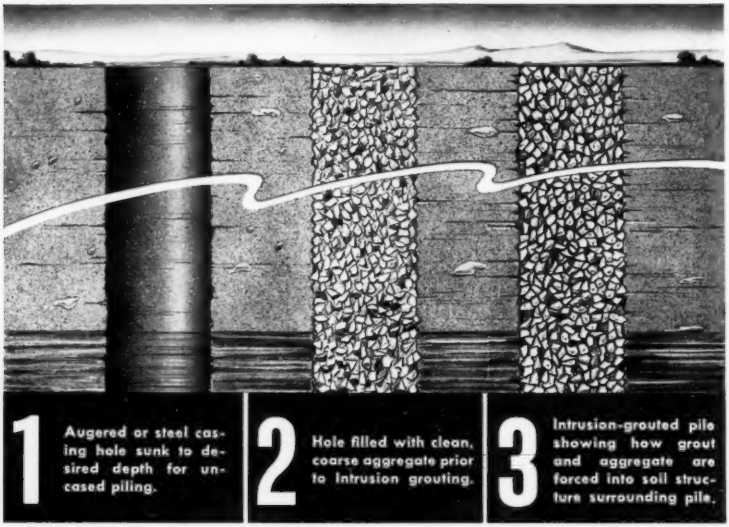
ACI News Letter

Vol. 22 No. 1 JOURNAL of the AMERICAN CONCRETE INSTITUTE September 1950



THREE STEPS TO IMPROVED CONCRETE PILES


1
Augered or steel casing hole sunk to desired depth for uncased piling.
2
Hole filled with clean, coarse aggregate prior to Intrusion grouting.
3
Intrusion-grouted pile showing how grout and aggregate are forced into soil structure surrounding pile.

PREPAKT CAST-IN-PLACE PILES

Prepakt Cast-in-Place Concrete Piles provide several great advantages for contractors and owners alike.

EASY TO PLACE—They are comparatively easy to place and may be cast in either augered or cased holes.

HIGH LOAD-BEARING STRENGTH—Shown (3) above, Prepakt uncased piles have thousands of friction-bearing areas created by the penetration of Intrusion grout into the ground structure surrounding the pile, thus adding greatly to the load-bearing strength of the pile.

DE-WATERING UNNECESSARY—Where pile hole watering conditions are encountered, it is not necessary to dewater holes to place Prepakt Cast-in-Place piling.

MONOLITHIC COLUMN—The Prepakt method of grouting from the bottom to the top of the aggregate eliminates all possibility of honeycomb or air and water pockets.

A Prepakt representative will be glad to show you, without cost or obligation, the advantages of Prepakt Cast-in-Place Piles as applied to your specific problem.

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Program announced for Washington meeting

Design of concrete mixtures for the interior of dams will be one of the featured topics at the ACI regional meeting in Washington, D. C., Oct. 24-26. Headquarters for the conference, which is expected to attract a large attendance from Eastern states, will be at the Mayflower Hotel in the capital city.

Properties of "no-fines" air-entraining concrete will be discussed as well as the precautions necessary in finishing pavements made with air-entraining concrete. Other problems in highway construction will be featured in various papers and one session will be devoted to an open forum on ready-mixed concrete.

Fred Burggraf, Assistant Director, Highway Research Board, will describe the special project being conducted in Southern Maryland by the Highway Research Board to evaluate the effect of concentrated truck traffic of various axle loads on rigid concrete pavements. This project is being financed by contributions of several state highway departments, in cooperation with the Bureau of Public Roads and industry, and is attracting nation-wide interest.

The construction of the $44,000,000 Chesapeake Bay Bridge will be described at one of the technical sessions and the closing day of the conference will feature an inspection trip to the bridge site.

The Washington committee, chairmanned by E. W. Bauman, Managing Director, National Slag Assn., has announced that hotel reservations should be made directly to the Mayflower Hotel, care of J. P. Flanigan, and with the designation that they are for the ACI conference.

The program chairman for the event is A. T. Goldbeck, ACI Vice-President and Engineering Director, National Crushed Stone Assn. Frank B. Brown, Managing Director, Wire Reinforcement Institute, has charge of registration; A. N. Carter, Manager, Highway Division, Associated General Contractors, heads the publicity committee; H. F. Clemmer, Engineer of Materials, District of Columbia, entertainment chairman; J. E. Dunn, District Engineer Portland Cement Assn., heads the committee that arranged the inspection trip; and S. S. Steinberg, Dean, College of Engineering, University of Maryland, educational contacts. ACI President Frank H. Jackson, Bureau of Public Roads, is ex officio member of the committee.

Program, Regional Meeting

Mayflower Hotel, Washington, D.C.

TUESDAY, OCTOBER 24

9:00 a.m.—REGISTRATION STARTS

12:30-2:00 p.m.—INFORMAL LUNCHEON

Get-together Tickets $3.00

2:00-5:00 p.m.—FIRST TECHNICAL SESSION

Chairman—
ACI President FRANK H. JACKSON,
Principal Engineer of Tests,
Bureau of Public Roads

Design of Concrete Mixtures for the Interior of Dams
BYRAM W. STEELE, Office of Chief of Engineers, Dept. of the Army

Precautions in Finishing Pavements Made of Air-Entraining Concrete
CHARLES W. ALLEN, Research Engineer, Ohio State Highway Dept.

Effective Sealing of Joints in Concrete Pavements
HAROLD F. CLEMMER, Engineer of Materials, District of Columbia

Investigation of Dowels and Other Load Carrying Devices for Transverse Joints of Concrete Pavements
HENRI MARCUS, Bureau of Yards and Docks, Dept. of the Navy

6:30 p.m.—OYSTER BAKE

Entertainment. Tickets $5.60

WEDNESDAY, OCTOBER 25

10:00 a.m.-12:15 p.m.—SECOND TECHNICAL SESSION

Chairman—
ACI Past President STANTON WALKER, Director of Engineering, National Ready Mixed Concrete Assn. and National Sand and Gravel Assn.

Forum on ready-mixed concrete

Construction of the Walnut Lane Bridge in Philadelphia, the first major prestressed bridge in the United States—

Motion picture in color by Portland Cement Assn.

2:00-4:15 p.m.—THIRD TECHNICAL SESSION

Chairman—
ACI Vice-President A. T. GOLDBECK,
Engineering Director, National
Crushed Stone Assn.

A Traffic Test to Determine the Effects of Heavy Loads on Concrete Pavements

FRED BURGGRAF, Assistant Director,
Highway Research Board

Application of Machine Technique to Concrete Housing Construction
Supplemented by film illustrating Ibec construction

WILLIAM V. REED, Vice-President,
Ibec Housing Corp., New York City

Construction of the Chesapeake Bay Bridge

Representative of J. E. Greiner Co.,
consulting engineers for the project

Properties of "No-Fines" Air-Entraining Concrete

RUDOLPH VALORE, JR., National Bureau
of Standards

THURSDAY, OCTOBER 26

9:00 a.m.—INSPECTION TRIP

Visit U. S. Naval Academy. Luncheon at Carvel Hall, Annapolis, and inspection by boat of construction of the Chesapeake Bay Bridge. Tickets $5.00, include luncheon and transportation.

The Mayflower Hotel has guaranteed accommodations for 100 persons. Reservations should be made direct with the hotel, addressed Mr. J. P. Flanigan, Mayflower Hotel, Washington, D. C., with the advice that the reservation is being made in connection with the ACI regional meeting.

So you're going to San Francisco?

Are you planning to attend ACI's 47th annual convention at the St. Francis Hotel, San Francisco, Calif., Feb. 20-22, 1951? With a program of planned widespread interest and appeal, the JOURNAL now and later presents suggestions to help members in planning their free-time hours.

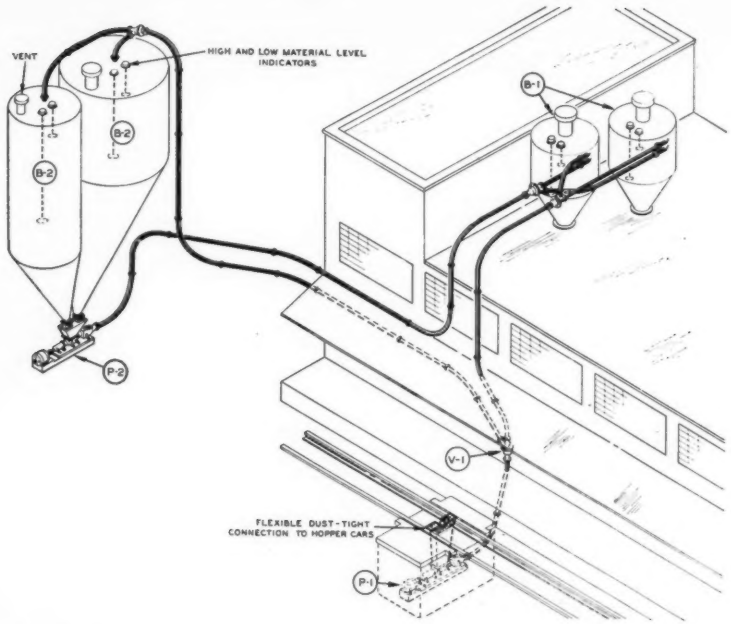
The San Francisco Bay area

The San Francisco Bay area (nine counties) is larger than Connecticut and Rhode Island combined, or a little smaller than New Jersey—yet only 4½ percent of California's area.

This small region is one of the major outlets for the far greater Central Empire of California, 1½ times the size of New York State and more than all New England, and from which comes more than half of California's wealth.

The San Francisco area is also noted for its beauty. From the bay the surrounding terrain slopes gently upward into rolling hills and mountains.

It's no wonder that San Francisco, strategically centered on the Pacific Coast and one of its foremost industrial and distribution points, has often been called the "nation's western capital."



Fuller-Kinyon System conveys either Portland cement or fly ash

The above illustrates how a cement-products plant in the mid-west uses the Fuller-Kinyon Conveying System for handling of two different materials, used in the manufacture of its product.

Portland cement and fly ash are received in hopper-bottom cars, fed by gravity to a Fuller-Kinyon Pump (P-1) in pit underneath railroad track. This pump conveys materials, through the use of a two-way valve (V-1), either direct to process bins (B-1), or to storage bins (B-2). A second Fuller-Kinyon Pump (P-2) conveys materials from bins (B-2) to process bins (B-1). A very simple and flexible system of unloading and conveying, economically possible only with Fuller-Kinyon Pumps.

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P-116

ACI JOURNAL Editors need help

—a kind of help a JOURNAL reader could give in a brief letter. The subject matter might come to your mind from a quick glance through the suggestions (a) to (h) that grow out of our need—ACI's need to improve in terms of doing. Always welcome in the day's mail is a letter about the techniques of producing good concrete structures; a letter giving fresh working experience and procedures, unawed by any compunction of erudition, and especially IF:

(a) that letter suggests a better way

(b) or takes issue with prevailing opinions of good concrete practice and gives reasons for the dissent

(c) or brings conviction of an idea worth trying

(d) or suggests the design of a concrete mix or of a concrete structure—joining *design* with its *execution* to correlate the design and specification intent with the ways and means of job practice

(e) or takes the idea of either of those (d) out on the job and makes it work under the pressures of actual creation of structures.

(f) or describes work within the general experience of many constructors—making no pretense of the best but of an economically workable solution

(g) or, better still, if you, the reader, throw the light of an experienced person's ideas on a single operation of a job—an operation performed on many jobs—variously poor, passable or superb, with sloppy or master workmanship—placing, finishing, or curing for instance

(h) or you offer a mere conjecture to illuminate a problem; hunches, conjectures often start a new line of thinking.

Such are often the things that come out in meetings of small groups. They rarely get onto a large formal program.

There is no shortage of exlfaustive (and often exhausting) reports of major studies of the properties of this and that kind or use of concrete, which certainly are not to be discouraged; they put lime in the backbone of growing knowledge. What we keenly need more of is from the builders or the job-conscious designers whose techniques give us useful, beautiful and enduring structures as final proof, or disproof, of the validity in the application of knowledge from such studies.

Perhaps we'd get along faster on the road to better and generally accepted concrete knowledge if more JOURNAL pages were written by those who know intimately the tools and the feel of concrete.

Who's Who This Month

Bengt F. Friberg

"Some Observations on the Use of Reinforcing Steel in Concrete Pavements," p. 1, are made by Bengt F. Friberg, Managing Director, Granco Steel Products Co., Granite City, Ill. The author was assisted by the members of Subcommittee 4 of ACI Committee 325, Structural Design of Concrete Pavements for Highways and Airports, of which Mr. Friberg is a member. The subcommittee members include L. M. Arms, William Van Breemen, C. A. Willson, Kenneth B. Woods and F. N. Wray.

Mr. Friberg, an ACI Member since 1928, has contributed various discussions in the JOURNAL pertaining to high elastic limit steel and is the author of several papers in other technical publications. He has approximately one dozen inventions for concrete construction to his credit, including the prestressing method "Stress Curing" and "COFAR," a concrete floor construction employing high-strength welded flat-rolled steel and bar assemblies.

He received a degree in civil engineering from the Royal Institute of Technology, Stockholm, Sweden, in 1924. After practicing structural engineering in Sweden, he came to the United States in 1927 with the American Bridge Co. and later the Laclede Steel Co.

During the war he served with the Corps of Engineers and in 1946 was appointed Chief Product Engineer of the Granite City Steel Co. He is now Managing Director for Granco Steel Products Co., a subsidiary of Granite City Steel Co., manufacturing steel products for concrete highway and building construction.

Robert A. Burmeister

Robert A. Burmeister, Materials Engineer, Dept. of Public Works, Milwaukee, Wis., submits data from "Tests of Paper Molds for Concrete Cylinders," p. 17. Author of several previous JOURNAL contributions, he has been an ACI Member since 1929.

Graduating in civil engineering from the University of Wisconsin in 1928, he was employed by the City of Milwaukee Testing Laboratory for two years. He then joined the staff of the Wisconsin State Highway Commission Materials Testing Laboratory and while there participated in numerous tests of concrete and mix designs covering several hundred Wisconsin aggregate sources. He states, "From these and later tests I formed a dim view of the practical value of the water-cement ratio."

In 1935 he moved to the Milwaukee division of the state highway commission and in 1942 assumed his present duties as Materials Engineer in charge of the testing laboratory for the City of Milwaukee. He is also consultant to the Milwaukee Central Board of Purchases on specifications, research and tests of materials.

Committee 212—Admixtures

Five papers are presented on p. 25 under the heading "Admixtures in Concrete" by members of ACI Committee 212, Admixtures.

F. H. Jackson

ACI President F. H. Jackson, Principal Engineer of Tests, U. S. Bureau of Public Roads, Washington, D. C., needs little introduction to JOURNAL readers. A member since 1924, he has been active on many technical and administrative committees as well as author of numerous JOURNAL contributions. As co-author with Harold Allen, his 1948 paper "Concrete Pavements on the German Autobahnen" was awarded the Wason Medal for the most meritorious paper.

Bruce E. Foster

Bruce E. Foster, Materials Engineer, is in charge of the Concrete Laboratory of the Mineral Products Division of the National Bureau of Standards, Washington, D. C. Besides being a member of Committee 212, he is also active on Committee 609, Vibration of Concrete.

Mr. Foster has been with the Bureau since 1935, most of which time was spent in the California acceptance testing laboratories. He was associated with the testing of pozzolan cement for Bonneville Dam and was in charge

of the Permanente branch laboratory which tested the cement for Shasta Dam and for the most of the war-period construction in the Pacific area.

A graduate of Colorado College, University of Oregon and Stanford University, Dr. Foster has served as graduate assistant at Oregon and Stanford and as teaching specialist in physics at Stanford.

W. T. Moran

Chairman of Committee 212, W. T. Moran, Chemical Engineer, U. S. Bureau of Reclamation, Denver, Colo., has been actively engaged in research work on portland cement and admixtures since 1932. He is head of the Bureau's chemical engineering section which performs research and development work in such varied fields as cement, admixtures, corrosion, paints, lubricants, asphaltic materials and chemical weed control methods.

Mr. Moran received his degree in chemical engineering from the University of Denver in 1931 and has been with the Bureau of Reclamation since, except for five years spent in the Army. Besides his ACI affiliation, he is a member of A.S.T.M. and the American Chemical Society.

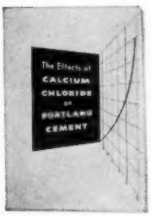
T. C. Powers

Also well-known to JOURNAL readers, T. C. Powers is Manager of Basic Research, Portland Cement Assn., Chicago, Ill., and has been the author of many JOURNAL articles and active on technical committees since 1927.

Three of his papers have reported noteworthy research for which he has been awarded the Wason Medal. They were for his work reported in his 1932 paper "Studies of Workability of Concrete," in his 1939 paper "The Bleeding of Portland Cement Paste, Mortar and Concrete," and with T. L. Brownyard for their 1946-7 series "Studies of the Physical Properties of Hardened Portland Cement Paste."

Prior to joining the Portland Cement Assn. in 1930, Mr. Powers was a chemist with the Oregon State Highway Commission, concrete technologist at Bull Run Dam and managed a ready-mix company. He advanced from Associate Engineer with PCA to Assistant to Director of Research in 1934 and was appointed to his present position in 1940.

HERE ARE THE FACTS
About the Use of CALCIUM CHLORIDE in Concrete



"The Effects of Calcium Chloride on Portland Cement" is a 40-page semi-technical book that tells you the facts about the use of Calcium Chloride in concrete. It describes in detail the carefully controlled tests that have been conducted by recognized authorities in the field and in the laboratory . . . and the results obtained.

Valuable Information For Contractors, Architects, Engineers, Plant Operators

Everybody who works with concrete—directly or indirectly—will be interested in this book. It gives factual answers to such question as . . .

- What happens when Calcium Chloride is added to air entrained cement. . . . to high early cement. . . . to low heat cement . . . to colored cement.
- What are the effects of Calcium Chloride on slump. . . . on flow. . . . on workability. . . . on density. . . . on water-cement ratio.
- What are the effects on setting time. . . . on early strength. . . . on ultimate strength.
- What are the effects on volume change and on surface wear.
- How much will Calcium Chloride reduce the curing period.
- What will Calcium Chloride do for cool and cold weather concrete.

These are just a few of the questions answered in "The Effects of Calcium Chloride on Portland Cement." In addition, there are graphs, tables, charts and much material that is now available for the first time in this book.

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"The Effects of Calcium Chloride on Portland Cement" is being made available without any cost or obligation by the Solvay organization. For your free copy, simply write on your business letterhead to Dept. JC-9, Solvay Sales Division, Allied Chemical & Dye Corporation, 40 Rector Street, New York 6, N. Y. Editions are limited so rush your request now.

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C. E. Goodell

C. E. Goodell, Chief Engineer, Russell Manufacturing Co., Caro, Mich., is the author of "Improved Sonic Apparatus for Determining the Dynamic Modulus of Concrete Specimens," p. 53. He was formerly Physical Research Engineer with the Michigan State Highway Dept. and an assistant professor of electrical engineering at Michigan State College. He has also worked with the Westinghouse Electric Corp. and the Naval Ordnance as a design engineer.

Mr. Goodell graduated from the University of Michigan in 1942 and received an M.S. degree from there in 1946. He is a member of the American Institute of Electrical Engineering, Institute of Radio Engineering, Tau Beta Pi, Sigma Xi, Eta Kappa Nu and Phi Kappa Phi.

Phil M. Ferguson

"Analysis of Three-Dimensional Beam-and-Girder Framing," p. 61, is by Phil M. Ferguson, Professor of Civil Engineering and Chairman of the Dept. of Civil Engineering at the University of Texas, Austin.

An ACI Member since 1930, he is a member of Committee 115, Research, with his chief fields of interest in frame analysis and reinforced concrete. Over the past ten years research on stress distribution in reinforcing steel, especially as modified by cracks, and questions of bond strength and bond stress distribution have occupied more and more of his time.

In speaking of the stress-strain characteristics of concrete beyond the point of maximum stress he states, "It seems evident to me that before long our theory of reinforced concrete beams must be revised in the direction of ultimate strength theories, such as have already been recognized in the case of columns. I am looking forward to the time when the Institute will assume leadership in this field."

After graduation from the University of Texas in 1922 and master's degrees from the University of Texas in 1923 and the University of Wisconsin in 1924, he spent several years with Dwight P. Robinson and Co. of New York City in structural design of power plants and industrial buildings and construction of hotels and apartment buildings.

Professor Ferguson returned to the University of Texas as associate professor in the field of structures and materials in 1928. He was raised to the rank of professor in 1939 and was made head of the civil engineering department in 1943. He has also been consultant on various projects.

Chester L. Post

Chester Leroy Post, consulting engineer for the Public Buildings Service, General Services Administration, and a prominent member of the American Concrete Institute since 1924, died suddenly of a heart attack in his Washington office Aug. 21, 10 days before he was to retire. He observed his seventieth birthday anniversary August 2.

Mr. Post was recognized as one of the nation's top-ranking engineers. He was associated with several prominent engineering firms in the Midwest, designing and building bridges, manufacturing plants and other types of construction, before he joined the government Jan. 24, 1942. He had worked on such major projects as the renovation and modernization of the White House, and the current construction of the General Accounting Office Building, in Washington, and the Clinical Center for the Public Health Service, at Bethesda, Md.

In 1935 he was appointed Chairman of the old Federal Works Agency's Advisory Construction Committee, made up of prominent private engineers, architects and builders. FWA's activities were absorbed by the General Services Administration July 1, 1949.

In 1939 he served as engineering investigator for a House Appropriations Subcommittee and in 1949 he was named to a committee appointed to consult with the National Security Resources Board.

During part of World War I, from 1918 to 1919, he was with the Army Quartermaster Corps in Brooklyn, N. Y., as special design engineer for the review of structural

designs, and in charge of expediting the procurement of materials.

Early in the century Mr. Post was connected with the Marquette Cement Co. as construction superintendent of the cement plant at LaSalle, Ill., the A. J. Yawger Co., Indianapolis, in charge of the construction of masonry buildings and sewers along the C.C.C. & St. L. Railway in Indiana and Ohio, and with the Unit Construction Co., Chicago, as general superintendent.

From 1910 to 1924 he was a member of the firm of the Condron Construction Co., Chicago, rising to vice-president and general manager. Later he became a partner of Gordon and Post, Chicago consulting engineers.

Born in Gordon, Ohio, Mr. Post received his B.S., Masters and Civil Engineering Degrees at the Rose Polytechnic Institute, Terre Haute, Ind.

Mr. Post was chairman of ACI Committee 318—Standard Building Code. He was also a member of the Chicago Engineers' Club, A.S.C.E., the Western Society of Engineers and the Chicago Shrine.

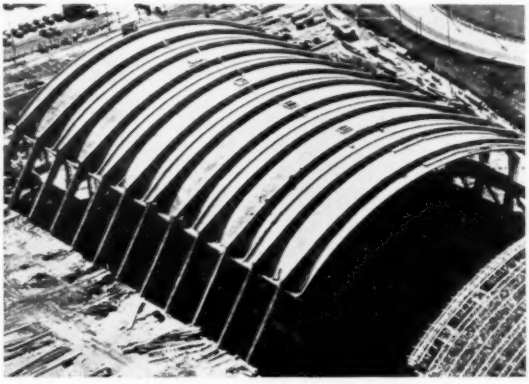
Dean Westergaard dies

Harald M. Westergaard, Gordon McKay Professor of Civil Engineering and former Dean of the Harvard Graduate School of Engineering, died at Cambridge, Mass., June 22. A native of Denmark, his U. S. career began at the University of Illinois in 1916; he became professor in 1927, and joined the Harvard faculty in 1936, becoming dean a year later.

In 1929-30, he was on leave from Illinois for technical studies on Hoover Dam for the U. S. Bureau of Reclamation. He also served the Bureau of Public Roads as a special analyst and senior mathematician on slab-design problems. He was also consulting structural engineer for the Bureau of Yards and Docks.

An ACI Member since 1920, he was the author of several JOURNAL contributions. His 1921 paper "Moments and Stresses in Slabs" was awarded the Wason Medal for most meritorious paper.

He authored many other technical papers, mostly on structural mechanics and the theory of elasticity. An authority on the elasticity of structural materials, he was noted in recent years for mathematical solutions of airport and building slab-design problems.



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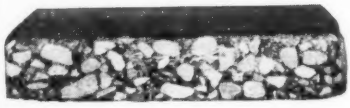

Cross Section of VANNIER Asphaltic Concrete Wearing Surface showing Aggregate Arrangement Designed to Carry Maximum Loads—both Moving and Static.

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Honor Roll

February 1 to July 31, 1950

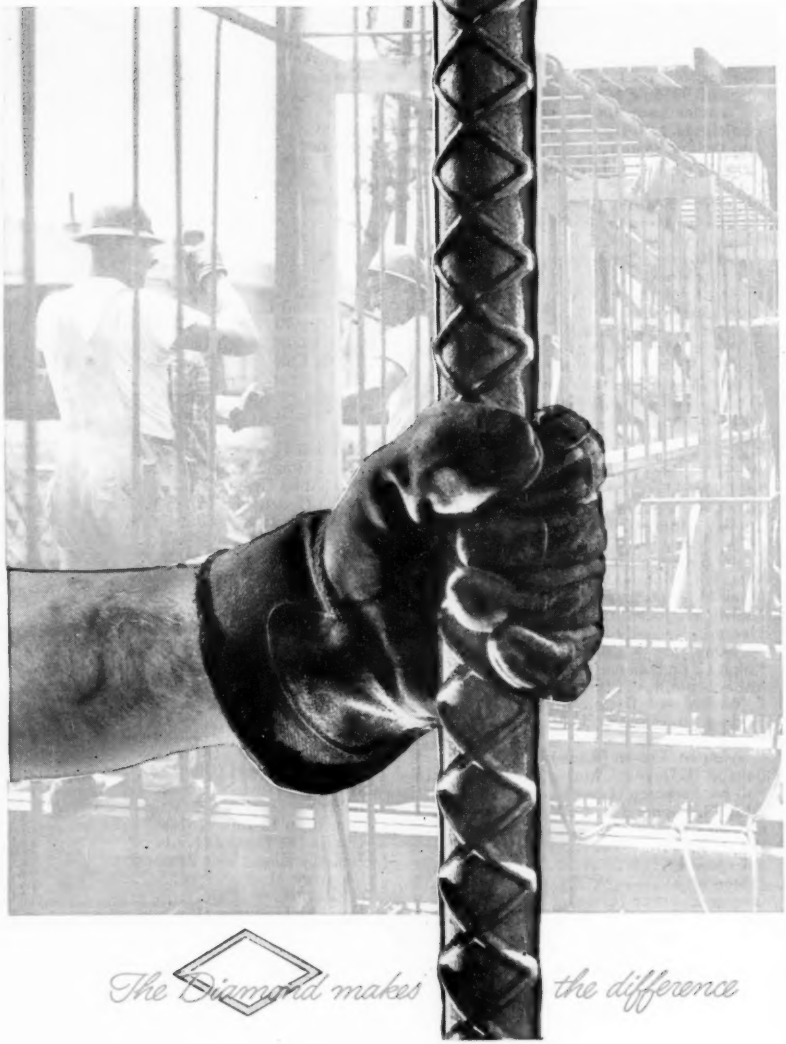
270 names, representing 5 percent of our total membership, are listed on our Honor Roll for the period ending July 31, 1950. The top ten on the list are responsible for a total of 98 new Members. We'd like to see a greater percentage of our membership participate actively in bringing new Members into the Institute.

What might YOU do about it?

Newlin D. Morgan (Ill.) **35½**
Newlin D. Morgan, Jr. (Wyo.) **17**
Henry E. Griset (N. C.) **7**
Leon Venegas (La.) **7**
E. I. Fiesenheiser (Ill.) **6½**
Chester P. Siess (Ill.) **6½**
Charles G. Peller (Ind.) **5**
George C. Alden (Calif.) **4½**
R. H. Sherlock (Mich.) **4½**
Luis A. Pietri-Lavie (Venezuela) **4½**
Cesar Oliver-Rugeles (Venezuela) **3½**
Andrew Reti (Venezuela) **3½**
Earl I. Brown (Ga.) **3**
Ashby T. Gibbons, Jr. (Ga.) **3**
Emil A. Gramstorff (Mass.) **3**
Walter N. Handy (Ill.) **3**
M. D. Hicklin (Ore.) **3**
James A. McCarthy (Ind.) **3**
Stanley Moore (Canada) **3**
H. J. Gilkey (Ia.) **2½**
Castor Segundo Goa (Venezuela) **2½**
Wm. T. F. Hooper, Jr. (Ill.) **2½**
Frank H. Jackson (D. C.) **2½**
Melvin W. Jackson (Ga.) **2½**
Henry L. Kennedy (Mass.) **2½**
A. Amirikian (Md.) **2**
Ralph L. Barbehenn (N. J.) **2**
Roberto Barillas F. (Guatemala) **2**
E. W. Bauman (D. C.) **2**
Sterling Lowe Bugg (Fla.) **2**
W. Fisher Cassie (England) **2**
Clayton M. Crosier (Kans.) **2**
Belmon U. Duval (Ohio) **2**
Phil M. Ferguson (Texas) **2**
Eddy N. Hernandez (La.) **2**
Orlando W. Irwin (Ill.) **2**
W. H. Jacobs (Ill.) **2**
J. E. Jellick (Calif.) **2**
J. Sterling Kinney (N. Y.) **2**
George E. Large (Ohio) **2**
William Lerch (Ill.) **2**
Leroy A. Staples (La.) **2**
S. J. Warberg (Mich.) **2**
J. F. Baxter (N. Y.) **1½**
Oscar Benedetti (Venezuela) **1½**
F. Thomas Collins (Calif.) **1½**
Jacob Cresskoff (D. C.) **1½**
Raymond E. Davis (Calif.) **1½**
Elmo C. Higginson (Colo.) **1½**
Samuel Hobbs (Calif.) **1½**
A. G. Timms (D. C.) **1½**
Jose Antonio Vila (Cuba) **1½**
Charles E. Wuerpel (Ill.) **1½**
Roderick B. Young (Canada) **1½**
Hugh Barnes (Calif.) 1
Hans H. Bleich (N. Y.) 1
Anthony Henry Clark (England) 1
E. F. J. Clark (Canada) 1
Roy R. Clark (Ore.) 1
Kenneth W. Clayton (Australia) 1
Aloysius E. Cooke (Conn.) 1
M. A. Craven (New Zealand) 1
R. A. Crysler (Canada) 1
Walter T. Daniels (D. C.) 1
Harmer E. Davis (Calif.) 1
Raymond E. Davis, Jr. (Calif.) 1
Charles W. DeGroff (N. Y.) 1
DeWitt Dieterich (Ill.) 1
H. B. Emerson (Ill.) 1
C. C. Everhart (Ia.) 1
Stanley Gordon Fisher (Canada) 1
George W. Ford (Fla.) 1
William E. Gabelman (Calif.) 1
Randall L. Gomien (Ohio) 1
H. F. Gonnerman (Ill.) 1
Nathaniel Grant (Mo.) 1
Ernst Gruenwald (N. Y.) 1
Gilberto Guardia (Panama) 1
Horace P. Hamlin (N. Y.) 1
Robert J. Hansen (Mass.) 1
Terrell R. Harper (Texas) 1
W. L. Harrell (Texas) 1
Charles E. Hawke (Canada) 1
Harry H. Hawley (Ohio) 1
Bernard C. Herring (England) 1
Thomas B. Kennedy (Miss.) 1
John C. King (Ohio) 1
K. V. Kini (India) 1
R. A. Kirkpatrick (N. Y.) 1
Blas Lamberti (Venezuela) 1
Leo M. Legatski (Mich.) 1
David V. Lewin (Ohio) 1
Harry E. Lewis (N. Y.) 1
Alvin C. Loewer, Jr. (Pa.) 1
Winthrop E. Luke (Mass.) 1
Charles L. Luther (Ky.) 1
Ian Macallan (New Zealand) 1
Glenway Maxon (Wis.) 1
G. T. McCoy (Calif.) 1
H. J. McGillivray (Fla.) 1
J. H. Murdough (Texas) 1
J. A. Murlin (Texas) 1
James A. Murray (Mass.) 1
J. Neil Mustard (Canada) 1
William D. Nowlin (Va.) 1
Oscar A. Nunez G. (Venezuela) 1
F. J. Ochoa U. (Guatemala) 1

Continued on p. 16

Better Bars



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CONCRETE REINFORCING BARS

YOU can count on extra anchorage between concrete and steel when you design your jobs with U·S·S Di-Lok, the improved concrete reinforcing bar that meets every requirement of ASTM Specification A305-49.

The U·S·S Di-Lok features that account for its exceptionally high bond strength are quickly evident in the photo at left. Note the extremely close spacing of diamonds on the bar. Note, too, the pronounced height of the ribs. These two features provide more grip, and a tighter grip per foot. This minimizes the tendency to slip under high loads and checks the formation of tensile cracks.

By taking advantage of the extra bond strength provided by U·S·S Di-Lok, you can minimize bending and other fabricating operations. And, in some cases, steel and concrete requirements can be reduced.

In addition to providing greater bond strength, the closely-spaced, diamond-pattern ribs also make for easier handling. U·S·S Di-Lok bars lie freely atop and beside one another. Do not interlock when bundled or stacked in racks. Thus, individual bars can be withdrawn freely.

U·S·S Di-Lok can be readily fabricated to meet close tolerances for all types of bends.

Made only from new-billet steel, U·S·S Di-Lok concrete reinforcing bars are available in standard sizes. Produced in six strategically located plants around the country: Pittsburgh, Pa.; Youngstown, Ohio; Gary, Ind.; Birmingham, Ala.; Pittsburg, Cal. and Torrance, Cal. Stocks are carried by leading fabricators in most principal cities.

To make your *next* job a *better* job, specify U·S·S Di-Lok. It is *the* reinforcing bar for building stronger, more durable concrete structures—and doing the job economically. Call us for the name of your nearest distributor.

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COLUMBIA STEEL COMPANY, SAN FRANCISCO
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM

USS

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UNITED STATES STEEL

Honor Roll

Continued from p. 13

Wm. Otcovsky (Ill.).....1
Kenneth K. Paget (Canada).....1
Jose Antonio Pardo B. (Mexico).....1
Howard F. Peckworth (Ill.).....1
Henry A. Pfisterer (Conn.).....1
Stanley A. Phillip (Ill.).....1
Dan H. Pletta (Va.).....1
Theodore O. Reyhner (Colo.).....1
Evan L. Richard (Australia).....1
Frank E. Richart (Ill.).....1
Horace B. Rickey, Jr. (La.).....1
Bernard L. Robinson (N. Y.).....1
Otto Sauermann (Ill.).....1
Emil Schmid (N. J.).....1
Wilfrid Schnarr (Canada).....1
James E. Schumann (Calif.).....1
Elwyn E. Seelye (N. Y.).....1
Thomas C. Shedd (Ill.).....1
Howard Simpson (Mass.).....1
E. R. Smallhorn (Canada).....1
Howard R. Staley (Mass.).....1
M. Eugene Sundt (N. M.).....1
Pascal L. Tasio (N. Y.).....1
Wm. H. Thoman (Colo.).....1
J. Neils Thompson (Texas).....1
H. F. Thomson (Ill.).....1
John H. Thornton (Scotland).....1
E. W. Thorson (Colo.).....1
LeRoy A. Thorssen (Canada).....1
G. K. Viall (Wis.).....1
F. E. Votaw (Mass.).....1
A. G. Watt (Pa.).....1
C. A. Willson (N. Y.).....1
S. H. Woodard (N. Y.).....1
A. E. Wynn (S. Africa).....1
Aubrey D. Young (La.).....1
R. A. Zern (Pa.).....1

The following credits are, in each instance "50-50" with another member.

James Adam, Jr.
J. B. Alexander
Frederick G. Anderson
James L. Atkinson
Malcolm F. Baker
C. Merrill Barber
George E. Barnes
Frank Baron
A. Allan Bates
K. P. Billner
G. L. Blanchard
A. E. Bond
J. G. Bragg
James E. Branch
Woodrow L. Burgess
R. A. Burmeister
D. J. Cameron
Julian B. Carson
Miles K. Cooper
William A. Crabb
A. E. Cummings
Clayton L. Davis
Charles W. De Groff
G. A. DeLong
Harry Delzell
A. H. Douglas
R. G. Douglas, Jr.
Leonard E. Dunlap
Harlan H. Edwards
W. J. Emmons
Jorge Figuls
John D. Freeman
Bernardo Fuentes A.
Mario W. Gamalero
J. H. Gandhi
Rodolfo C. Garcia
A. H. Garnsey
A. T. Goldbeck
O. H. Gosswein
Alex H. Graves
Homer M. Hadley
William H. Hall
W. C. Hansen
Harvey L. Harris
George E. Hatch
John M. Hayes
William N. Holway
Wilfred M. Honour
J. W. Hubler
Virgil L. Hughes
Maurice Hunt
S. E. Hyde, Jr.
Raja A. Iliya
W. R. Ingram
C. E. Ireland
C. L. N. Iyengar
Arthur M. James
M. E. James
Bernerd D. Keatts
Edgar R. Kendall
Frank Kerekes
W. D. Kimmel
W. P. Kinneman
Ralph W. Kluge
Paul P. Kraai
J. E. Lothers
Irvin H. Luke
I. D. MacKenzie
M. F. Macnaughton
James V. Mandia
W. T. McClenahan
Sam McCluer
C. T. J. McDowell
A. J. McElrath
Douglas McHenry
Harmon S. Meissner
Henry L. Neve
Roy A. Nyquist
Raymond G. Osborne
John P. Ottesen
Thomas Poli
Milos Polivka
Chesley J. Posey
Leo F. Pratt
Raymond C. Reese
Frederick A. Reichert
Guy Rinfret
Charles S. Rippon
A. Rodriguez-Delfino
Pedro Rodriguez
Paul Rogers
Mark R. Rosumny
Oswaldo Rovati B.
William H. Rowan
John A. Ruhling
Frederic Rusche
Nicholas R. Samaha
R. W. Sauer
D. M. Schmid
Axel Schulze
J. Morgan Smith
Myron M. Smith
Ernest L. Spencer
John J. Stedje
Byram W. Steele
John D. Stites
Herbert M. Stoll
Ernest O. Sweetser
L. W. Teller
George P. Thigpen
B. K. Thornley, Jr.
T. Thorvaldson
G. E. Troxell
Paul M. Trueblood
Lee Turzillo
Lewis H. Tuthill
Miguel Villa
Julius J. Warner
G. E. Warren
Willard W. Warzyn
W. R. Waugh
Clement T. Wiskocil
Francis P. Witmer
Bourdette R. Wood
H. D. Worthington
George D. Youngclaus

Bridge stresses investigated

A joint project by the California Division of Highways and the Institute of Transportation and Traffic Engineering, University of California, will compare actual stresses in highway bridges with the values calculated for purposes of design.

Consisting of a concrete slab placed directly on steel beams, the bridge was selected as representative of a common current type. Strain gages have already been placed and a number of static-load readings taken. In about two months, when construction has progressed far enough for the bridge to accomodate test-load vehicles, dynamic readings will be recorded.

Measurements will be taken at more than 200 gage stations distributed over 39 general locations throughout the structure. Whittemore gage points were placed on steel members at the fabricating plant; SR-4 strain gages have been mounted at various points on the installed steel; and Carlson gages are being used in the concrete deck.

Special truck-trailer combinations will be used for dynamic-load testing. These will be recorded by mobile oscillographic equipment.

Included on the advisory committee for the project are four ACI Members; Howard Eberhardt, University of California; Tung Y. Lin, Institute of Transportation and Traffic Engineering; Stewart Mitchell, principal bridge engineer, California Division of Highways; and Glen B. Woodruff, consulting engineer, San Francisco.

Positions and Projects — ACI Members

Henry M. Shaw

Henry M. Shaw, resident engineer at Weldon, N. C., for the North Carolina Highway Department, has been transferred to Warrenton where he will supervise road construction in Warren County.

Anderson becomes general manager

Harry C. Anderson, Chief Engineer, and chairman of the Highway Board of British Columbia, Canada, is retiring to become general manager of the General Construction Co. and its subsidiaries. Well-known in the Fraser Valley, where he was district engineer for years, Mr. Anderson came to the top of the works department in 1947, just as British Columbia launched its big road rebuilding program.

Downs transferred to irrigation project

L. Vaughn Downs has been transferred by the Bureau of Reclamation from Grand Coulee Dam to Ephratta, Wash., as chief of the field engineering subdivision of the Columbia Basin Project's irrigation district. He has been construction engineer in the Coulee Dam division of the project. In his new assignment, Mr. Downs will be responsible for the location of hundreds of miles of lateral canals and the layout of farm units in connection with the irrigation of thousands of acres in the project, which will begin to get water in 1952.

Pelsue directs research activities

H. F. Garvin Pelsue, former president of the Metropolitan Sand and Gravel Corp., New York, N. Y., and a past president of the National Ready Mixed Concrete Assn., Washington, D. C., is now associated with Jaeger Machine Co., Columbus, Ohio, in charge of research. He also heads the company's advisory engineering service to ready-mixed concrete producers. Mr. Pelsue, an ACI Member since 1937, served for 20 years in production and sales with Graham Brothers, Inc., Los Angeles, Calif., including seven years as executive vice-president. He moved to New York in 1942 to assume management of the Metropolitan Sand and Gravel Corp., and direct its expansion into the ready-mixed concrete business. He became president in 1944 and served until 1949.

Meihaus named president of Texas group

George A. Meihaus, Jr., executive vice-president and general manager of Texcrete Co., Fort Worth and Dallas, Texas, has been elected president of the Texas Concrete Masonry Assn. He succeeds John P. Sheehan, Atlas Lime Co., El Paso, who has been elected a director of the Association.

Colburn elected to board of directors

D. S. Colburn, vice-president of Marquette Cement Manufacturing Co., Chicago, Ill., has been elected a member of the board of directors in addition to his duties as vice-president.

Mr. Colburn joined the company in 1924 as service engineer and subsequently supervised construction of a major addition to the Oglesby, Ill., plant. He was made vice-president in 1933.

Annual reports of cement manufacturers win awards

From almost 5000 corporation annual reports for 1949 submitted in the tenth annual survey conducted by *Financial World*, nine cement companies have qualified for "Highest Merit Award" citations. The nine companies, all ACI Members, are Bessemer Limestone and Cement Co., Consolidated Cement Corp., General Portland Cement Co., Ideal Cement Co., Lehigh Portland Cement Co., Lone Star Cement Corp., Marquette Cement Manufacturing Co., Missouri Portland Cement Co. and Permanente Cement Co.

The reports of these companies thus become candidates for the final judging for a "Best of Industry" award. Last year six ACI Member companies received citations for annual reports and a year ago the 1948 annual report of Marquette Cement Manufacturing Co. won the trophy for the best report in this industrial classification.

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Construction Methods, Supervision

ASA announces awards to ACI Members

Harry C. Plummer, Director of Engineering and Research, Structural Clay Products Institute, Washington, D. C., and Maurice N. Quade, Parsons, Brinckerhoff, Hall and MacDonald, Engineers, New York, N. Y., were awarded certificates by the American Standards Assn. in recognition of their work in the development of industrial standards as members of the A. S. A. Standards Council.

The Standards Council formulates rules for standards development and approves standards that are supported by a concensus of those concerned with them. It also decides what projects to develop, their scope, and makes sure that personnel of the committees working on standards represent all who are concerned.

One of the principal purposes of the association is to coordinate standardization work of many national organizations to assure standards that have inter-industry recognition on a nation-wide scale without duplication of effort by the organizations involved.

Concrete pipe industry expands activities

The newly organized American Concrete Agricultural Pipe Assn. recently affiliated with the American Concrete Pipe Assn. and the American Concrete Pressure Pipe Assn. The three national concrete pipe associations will coordinate their activities as members of a joint coordinating and affiliating association, Concrete Pipe Associations, Inc., under the direction of Howard F. Peckworth, Managing Director.

The American Concrete Agricultural Pipe Assn. was organized last June by a group of manufacturers of concrete irrigation pipe and concrete drain tile. ACI Member Elmer L. Johnson, Concrete Conduit Co., Colton, Calif., was elected Director-at-Large of the new organization.

Davis named HRB committee chairman

Harmer E. Davis, director of the Institute of Transportation and Traffic Engineering of the University of California and general convention chairman for ACI's 1951 meeting in San Francisco, has been named chairman of the Highway Research Board's Committee on Highway Organization and Administration.

The broad purpose of the committee is to study the organization and management of highway activities on all government levels with respect to organizational forms, efficiency, extent of jurisdiction and specific functions. It will devote its attention particularly to road department organization at county and city government levels.

Interested in "Rock Products"?

The Institute regularly receives the publication *Rock Products* and needs a reviewer for it. The magazine carries articles on the aggregate, cement, and concrete industries. Anyone interested in reviewing this periodical please write the ACI for further information.

Pontusco purchases United Concrete Pipe Corp.

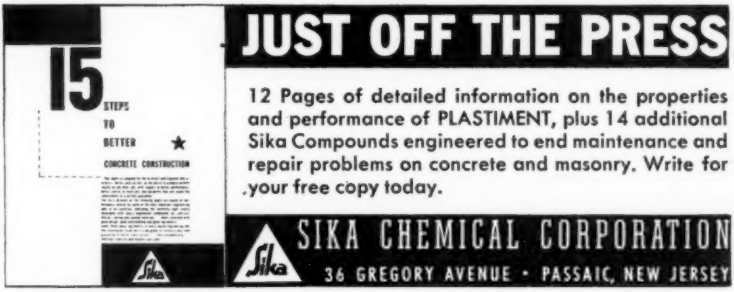
The Pontusco Corp., Burlington, N. J., has announced the purchase of United Concrete Pipe Corp., Baldwin Park, Calif.

An ACI Member since 1948, United Concrete Pipe Corp. was founded in 1918 as the United Concrete Pipe Co. and was incorporated in 1929. They manufacture reinforced concrete pressure pipe and low pressure concrete pipe in ten plants in California and Utah.

Westergaard library offered

The technical library of the late Prof. H. M. Westergaard, including bound *Proceedings* of the American Concrete Institute, 1909-1949; unbound ACI JOURNALS, Nov. 1913 to Aug. 1915 and from Nov. 1929 to Apr. 1950; and yearly ACI Directories has been offered for sale. Bound volumes of *Cement Age*, 1904-1909 and 1912 are also available.

Inquiries should be directed to Peter Talbot Westergaard, Pierce Hall, Harvard University, Cambridge, Mass.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M. W. Jackson

Prof. M. W. Jackson, formerly at Georgia Tech, has joined the staff of the Dept. of Civil and Architectural Engineering, University of Colorado, Boulder, Colo.

Hollister resigns cement company presidency

C. T. W. Hollister, president of the Northwestern Portland Cement Co., Seattle, Wash., and one of the company's founders, resigned recently from that position which he has held since 1932. He has been active in the cement industry for more than 50 years. Mr. Hollister will continue as a member of the Board of Directors, and Chairman of the Executive Committee for the company.

ACI Members advise Mackinac Bridge Authority

Three of the outstanding bridge engineers in this country, Othmar H. Ammann, D. B. Steinman and G. B. Woodruff, have been retained by the Mackinac Bridge Authority to study the feasibility of connecting Michigan's two peninsulas across the Straits of Mackinac. The three men have been identified with practically every long-span structure built in this country and many of those abroad.

Mr. Ammann, New York City, ACI Member since 1946, has been identified with some of the greatest bridge structures in the world: Queensboro Bridge and Hell Gate Bridge, New York; Golden Gate Bridge, San Francisco; Kill Van Kull Bridge, Bayonne, and a score of others.

Mr. Steinman, also of New York City and affiliated with ACI since 1927, has won many prizes for design and beauty of bridge structures. His Florianopolis Bridge in Brazil is the largest in South America. The author of numerous papers on bridge design, Mr. Steinman has been associated with just as impressive a list of long-span bridges as Mr. Ammann, and both are doing design work on a bridge across the Narrows in New York which will have a 4620-ft span. He is also working on plans for a bridge across the Straits of Messina connecting Italy and Sicily requiring a 5000-ft span.

The third consultant, Mr. Woodruff, has been an ACI Member since 1928 and has been design engineer on the San Francisco-Oakland Bay Bridge, the Golden Gate Bridge, the rebuilt Tacoma Narrows Bridge, the Ambassador Bridge and others.

Engineer positions open in Bureau of Reclamation

The U. S. Civil Service Commission has announced an examination for Engineer to fill positions paying $4600 to $5400 a year in the Bureau of Reclamation. The positions are located in various states in the West and Midwest. Education and engineering experience are specified.

Information and application forms may be obtained from the U. S. Civil Service Commission, Washington 25, D. C.

Reviewer for *Civil Engineering*

The British publication *Civil Engineering and Public Works Review* is now being received by the Institute. The magazine carries articles on various phases of civil engineering including concrete design and construction. Anyone desiring to volunteer as a reviewer please write the Secretary.

ACI Members honored by A.S.T.M.

Two ACI Members, P. H. Bates, St. Petersburg, Fla., and W. C. Hanna, Colton, Calif., received Honorary Memberships from A.S.T.M. at its June meeting in Atlantic City.

Mr. Bates has been an active ACI Member since 1926 and is the author of numerous JOURNAL papers. He was awarded the ACI Henry C. Turner Medal in 1939 for "contributions to science, direction of research and outstanding leadership in advancing the intelligent utilization of cement and concrete." He was Chief, Clay and Silicate Products Division, National Bureau of Standards for many years, and was A.S.T.M. president, 1944-45, and ACI president, 1934-36.

Mr. Hanna, Chief Chemist and Chemical Engineer, California Portland Cement Co., has also contributed to the JOURNAL pages. He began his industrial work with his present company in 1903 and pioneered in the chemical analysis of cement. He received the 1948 Sanford E. Thompson Award from A.S.T.M. for his paper on chemical reactions of aggregates.

Seabee Reserve enlistments open

Skilled construction men over the age of 25 can still enlist in the Naval Reserve as Seabees and receive petty officer ratings equal to their civilian experience, the Navy has announced.

Depending on the kind and amount of civilian experience, skilled construction men can expect to be rated at some point in the scale between Chief Petty Officer and Third Class Petty Officer.

The seven Seabee ratings open cover about 60 different civilian construction skills. These ratings are: Builder, Mechanic, Steelworker, Utilities Man, Construction Electrician, Driver and Surveyor. Volunteers will be placed on inactive duty with no drills or required meetings. They may be called to active duty when required.

Enlistment in the Volunteer Reserve is limited to men in the 26-45 age group. The upper age limit is extended in case of veterans to the same number of years beyond age 44 as their previous military service. The opportunity to join this standby reserve is no longer available to men in the 19 to 25 age group because they have become subject to induction under the Selective Service Extension Act of 1950.

Those desiring further information should get in touch with the Commanding Officer of any Organized Reserve Construction Battalion Company or Volunteer Construction Battalion Reserve Unit, located in more than 300 principal cities throughout the country.

Lin joins Institute of Transportation and Traffic Engineering staff

Tung Y. Lin, associate professor of civil engineering, University of California, Berkeley, and a member of ACI Committee 314, Rigid Frame Bridges, recently joined the staff of the Institute of Transportation and Traffic Engineering at the University of California. He will specialize in highway bridge studies.

After graduating from Chiaotung University in China, Mr. Lin received an M.S. degree in civil engineering at the University of California in 1933. Returning to China, he worked with the Chinese National Government Railways, becoming chief of design and planning for the Yunaan-Burma Railway. He joined the University of California staff in 1946 as assistant professor and was appointed associate professor in 1949.

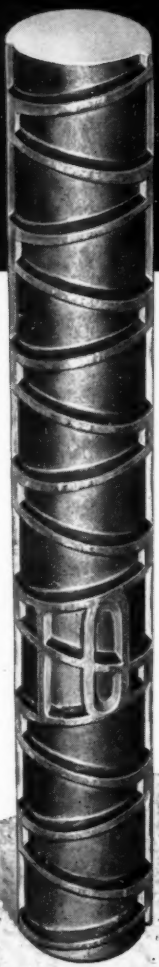
Scrap iron in concrete for radiation protection

Better protection from atomic radiation, hazard near atomic installations, is given by a mixture of cement, scrap iron and limonite, an iron ore.

Drs. P. C. Gugelot and M. G. White, Palmer Physical Laboratory of Princeton University, Princeton, reported in the May *Journal of Applied Physics* that they have discovered that a 3-ft wall of iron and limonite concrete is 280 times as effective as ordinary concrete in stopping neutrons and 20 times as effective in stopping gamma radiation.

The scrap iron-limonite concrete has satisfactory mechanical properties for structural purposes. It is, however, more expensive than a concrete made entirely of limonite so that the limonite concrete could be used where cost was a limiting factor.

GETS A FIRM GRIP IN CONCRETE



The size of each Bethlehem Bar is easily determined by means of numeral rolled into the bar.

The improved Bethlehem Reinforcing Bar provides maximum bond-strength because its high, closely-spaced lugs get a firm grip in the concrete . . . hold the bar securely for the life of the structure. These lugs equal the height called for in ASTM Specification A305-49. The resulting firm anchorage means low slips at working loads, which in turn help prevent the formation of wide tensile cracks in the concrete.

The Bethlehem Reinforcing Bar is made from new-billet steel in all sizes from ⅜ in. to 1¼ in. It meets every requirement of ASTM Specification A305-49. Always ask for the Bethlehem Bar to be sure of firm anchorage.

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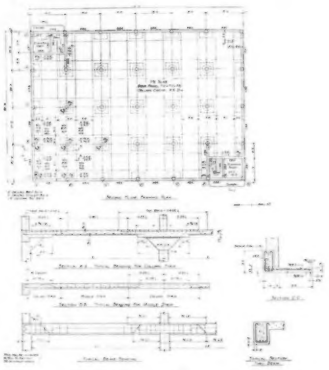
BETHLEHEM REINFORCING BARS

Manual of Standard Practice for Detailing Reinforced Concrete Structures

(ACI Standard 315-48)

for the

Designer
Detailer and
Student



$3.00 (to ACI Members—$1.75)

The **Manual** presents accepted methods and standards for preparing drawings for the fabrication and placing of reinforcing steel. The use of these methods and standards results in better reinforced concrete construction and also simplifies and reduces the amount of work ordinarily required to prepare such drawings.

The fundamental purpose of all "engineering drawings" is to enable the builder to transform the designer's calculations and design into the structure he has conceived. These drawings give the information necessary for building forms and placing concrete and for preparing the "placing drawings" (sometimes called "detail drawings") which must contain the information necessary for fabricating the reinforcement and placing it in the forms.

The **Manual** illustrates typical engineering and placing drawings prepared according to the standards. The designs are not intended as standard designs, although in general they meet the requirements of the American Concrete Institute's "Building Code Requirements for Reinforced Concrete" (ACI Code). They are intended to show **standard detailing methods.**

AMERICAN CONCRETE INSTITUTE 18263 W. McNichols Rd. Detroit 19, Mich.

The Detailing Manual includes—

Drawing standards—Standards and comments on size of sheet, layout, scales and symbols.

Marks—Discussion of systems of marking members and reinforcement.

Schedules—Discussion of types of schedules and recommendations for their use.

Engineering drawings—Information required on drawings and best methods of showing it.

Placing drawings—Best methods of showing necessary information.

Fabricating detail standards—Standards for bending, hooks, stirrups, typical bar bends, slant lengths, beam widths, spirals, ties, column verticals, splices and dowels.

Notes to designers and detailers—Attention is called to points which frequently are overlooked or which cause trouble. Conformance with the suggestions given eliminate most difficulties of interpretation, fabrication and construction.

Shop procedure—Brief description of steps in the shop.

Warehouse stock—Notes material usually carried in stock.

Tolerances—Standard tolerances in dimensions of fabricated reinforcement.

Extras—Basis for extra charges for material and fabrication.

Welded wire fabric—Data on fabrication, size limitations, detailing and common styles.

Accessories—Standard accessories and their use.

Typical drawings—21 typical engineering and placing drawings are shown for various structures to illustrate the use of the standards and methods advocated in the manual. A short discussion of the important points accompanies each drawing.

Typical drawings

The engineering drawings used in the manual were selected from plans of actual structures but have been modified in some details to conform more closely with the ACI Code and to illustrate recommended methods of presenting the information. Shop prepared placing drawings accompany each engineering drawing.

- Concrete joist floor
- Flat slab floor
- Beam and girder floor
- Two-way slab and beam floor
- Foundations
- Columns
- Architectural concrete building
- Wall details
- Stair details
- Circular tank
- Rigid frame bridge

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New Members

207 new Member applicants were admitted to Institute membership during the three months' period, May 1 through July 31. Of that number 27 percent reside outside of the United States—73 percent domestic.

California was top membership state for the period with 19 new Members; Illinois was close behind with 18; Canada had 15 and Venezuela 14.

Alabama

Armentrout, W. F., (Indiv.) 535 American Life Bldg., Birmingham 3, Ala.
Landel, A. W., (Indiv.) Connors Steel Co., P. O. Box 2562, Birmingham, Ala.
Wallace, George J., (Jr.) A. C. Samford Co., P. O. Box 772, Auburn, Ala.

California

Buck, Herbert H., (Indiv.) County of Los Angeles, Mechanical Dept., Fourth Floor—Engineering Bldg., 108 W. Second St., Los Angeles 12, Calif.
Dickman, "W" Bernard, (Indiv.) 918 Harrison St., San Francisco 7, Calif.
Dunham, Bert R., (Indiv.) Southwestern Portland Cement Co., Victorville, Calif.
Harris, Mary Jean, (Jr.) 4315 Arcadia Dr., San Diego, Calif.
Henderson, George L., (Jr.) 463 Virginia Ave., San Mateo, Calif.
McClaskey, James F., (Jr.) 1942 F St., Eureka, Calif.
Neumann, M. R., (Indiv.) 3405 Piedmont Ave., Oakland, Calif.
Oliver, William H., (Jr.) U. S. Bureau of Public Roads, 180 New Montgomery St., 6th Floor, San Francisco 5, Calif.
Parker, George Kempton, (Indiv.) 926 8th St., Bakersfield, Calif.
Peterson, E. J. L., (Indiv.) District Engineer, Division of Highways, P. O. Box 841, San Luis Obispo, Calif.
Sanner, Walter Edward, (Indiv.) 1215 Van Ness Ave., San Francisco 15, Calif.
Sayler, Francis Albert, (Indiv.) 7421 W. Beverly Blvd., Los Angeles, Calif.
Silvert, Mac, (Indiv.) 112 Market St., Room 230, San Francisco 11, Calif.
Smice, Robert E., (Indiv.) Room 1412, Russ Bldg., San Francisco 6, Calif.
Sumner, Fred, (Indiv.) c/o A. C. Horn Co., Inc., 252 Townsend St., San Francisco 7, Calif.
Ward, Dwight A., (Indiv.) 800 W. Hyde Park Blvd., Inglewood, Calif.
Weintz, Byron P., (Indiv.) Chief Engineer, Consolidated Rock Products Co., P. O. Box 2950—Terminal Annex, Los Angeles 54, Calif.
Whipple, John H., (Jr.) 246 Elena Ave., Atherton, Calif.
Winkler, Herbert G., (Jr.) Shady Oak Trailer Court, O'Neals, Calif.

Colorado

Butz, Jack Richard, (Jr.) 958 S. Franklin, Denver, Colo.
Gerdes, H. G., (Indiv.) Post Engineer, Camp Carson, Colo.
Jeffres, Thomas Paul, (Jr.) 2411 Yale Ave., Denver 10, Colo.
Kelher, R. S., (Indiv.) Chief Chemist, Ideal Cement Co., (Fremont County) Portland, Colo.
Umberger, John David, (Indiv.) 800 S. Corona St., Denver 9, Colo.

Connecticut

Corbett, Milton T., (Indiv.) 47 Canner St., New Haven 11, Conn.

District of Columbia

Larson, C. E., (Indiv.) Division Two, Bureau of Public Roads, U. S. Dept. of Commerce, Washington 25, D. C.
McAlpine, William H., (Indiv.) Office Chief of Engineer, U. S. Army, Washington, D. C.

Florida

Cajina Rios, Adan, (St.) General Delivery, University Station, Gainesville, Fla.
Tingle, Edward, (Indiv.) 1032 NW 53rd St., Miami 37, Fla.

Georgia

Knowlton, Robert L., (St.) 2080 N. Decature Rd., N. E., Atlanta, Ga.
Pahno, Leon N., (St.) Box 5045, Georgia Institute of Technology, Atlanta, Ga.

Illinois

Anderson, A. A., (Jr.) 111 W. Washington St., Chicago 2, Ill.
Emmett, Robert C., (Indiv.) 411 N. LaSalle St., Chicago 10, Ill.
Fallon, Joseph Michael, (Jr.) Fairmount Addition, Alton, Ill.
Friedland, Albert Wolfgang, (St.) 907 S. Third St., Champaign, Ill.
Fuller, George Loren, (Jr.) 121 Arlington Ave., Peoria, Ill.
Haley, William A. III, (Indiv.) c/o American Concrete Pipe Assn., 228 N. LaSalle St., Chicago, Ill.
Hanson, W. E., (Indiv.) 218 Civil Engineering Hall, University of Illinois, Urbana, Ill.
Jantho, Edwin Louis, (Jr.) 3911 Dakin St., Chicago 18, Ill.
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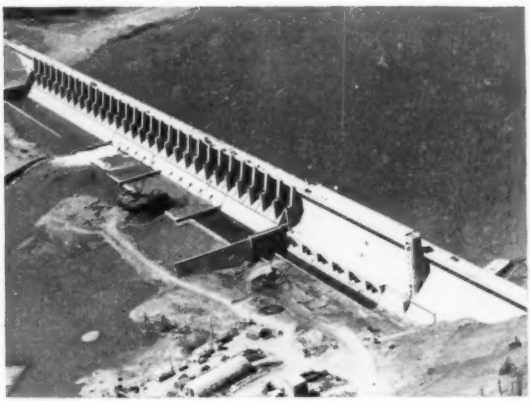
Continued on p. 26

Darex AEA

is a catalyzed air entraining agent, *specifically formulated* for making air entrained concrete.

Darex AEA

is being used in all types of concrete work, all over the world.
Distribution warehouse stocks are conveniently located throughout North and South America and in most foreign countries.



The very lean mixes used in dams and other mass concrete construction are usually quite difficult to place. Darex AEA concrete was used in the Fort Gibson Dam, Grand River, Oklahoma, to increase placeability . . . eliminate the use of excess water, reduce bleeding.

DEWEY AND ALMY CHEMICAL COMPANY
CAMBRIDGE 40, MASSACHUSETTS
CHICAGO 38 MONTREAL 32

DAREX REG. U. S. PAT OFF

New Members

Continued from p. 24

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Newell, J. R., (Indiv.) 228 N. LaSalle St., Chicago, Ill.
Reagel, Fred S., (Jr.) Marquette Cement Mfg. Co., 20 N. Wacker Dr., Chicago 6, Ill.
Rittweger, William Henry, (Indiv.) 2517 N. Sawyer Ave., Chicago 47, Ill.
Sauermann, Gerhardt H., (Indiv.) 2032 W 103rd St., Chicago 43, Ill.
Schutz, Frederick Wm. Jr., (St.) 201 S. Wright St., Champaign, Ill.
Seyler, Jimmy W., (Jr.) H-41B Stadium Terrace, Champaign, Ill.
Spitzer, Harry J. Jr., (St.) 3342 W. Warner Ave., Chicago 18, Ill.
Taylor, James L., (Indiv.) c/o International Minerals & Chemical Corp., 20 N. Wacker Dr., Chicago 6, Ill.

Indiana

Buettner, Carl F., (St.) 606 Brown St., Valparaiso University, Valparaiso, Ind.
Phelps, Boyd E., (Indiv.) 1000 Washington St., Michigan City, Ind.
Porwancher, Kenneth F., (St.) R. R. 5, Valparaiso, Ind.
Thompson, Raymond C., (St.) Trailer Court, Valparaiso University, Valparaiso, Ind.
Vellines, Robert Price, (Indiv.) 116 S. Clark Rd., Gary, Ind.

Iowa

Gaynor, Keyes Christopher, (Indiv.) Benson Bldg., Sioux City, Ia.
Lowry, Aaron Wilbur, (Jr.) Box 137, Adair, Ia.
Pierson, C. U. Jr., (Indiv.) c/o Marquette Cement Mfg. Co., 52nd & Park Ave., Des Moines 5, Ia.

Kentucky

Distefano, Alfred G., (Indiv.) P. O. Box 291, Lousville, Ky.

Louisiana

Cook, Charles William, (Indiv.) Route 2, Pollock, La.
Lasseigne, Clifton C., (St.) 111 N. 4th St., Apt. 15, Baton Rouge, La.
Patino, Reynaldo, (St.) Louisiana State University, P. O. Box 8085, Baton Rouge, La.
Steele, Maitland Allen, (Jr.) 317 Eleventh St., Lake Charles, La.
Tudor, Robert B., (Indiv.) P. O. Box 1232, 1284 Murray St., Alexandria, La.

Maine

Galli, James Henry, (Indiv.) 34 Orhney St., Portland 5, Maine

Maryland

Ritchie, Marguerite, (Indiv.) Engineering Librarian, Glenn L. Martin College of Engineering, University of Maryland, College Park, Md.

Massachusetts

Formo, Reidar K., (St.) MIT's Dorms, Cambridge 39, Mass.
Souza, Richard W., (Jr.) 7 Lucille Place, Newton Upper Falls 64, Mass.

Michigan

Bradley, William A., (Jr.) Civil Engineering Dept., Olds Hall, Michigan State College, East Lansing, Mich.
Jackson, Frederick N., (Indiv.) Scott Engineering Co., Alpena, Mich.

Missouri

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Cummings, Pat, (Indiv.) 711 Paseo, Kansas City 6, Mo.
Kuntemeier, W. F., (Indiv.) 1317 Arcade Bldg., St. Louis 1, Mo.
Sykes, J. D. Jr., (St.) 70 Frederick Lane, Glendale 22, Mo.

Montana

Volk, Arthur Clarence Jr., (Jr.) U. S. Bureau of Reclamation, Columbia Falls, Mont.

Nebraska

Hensing, Emmett H., (Indiv.) 5624 Hickory St., Omaha 6, Nebr.
Jizba, Jaroslav Z., (Jr.) 2566 Evans St., Omaha 10, Nebr.
Sharp, R. E., (Indiv.) Chief Chemist, Ideal Cement Co., Superior, Nebr.
Steinbart, Reinhardt, (St.) 805 Williams Ave., Omaha, Nebr.

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Armento, William J., (Indiv.) 70 Van Pelt Ave., Staten Island 3, N. Y.
Costello, Daniel E., (Indiv.) 90-31 Whitney Ave., Elmhurst, L. I., N. Y.
Crawley, Stanley W., (Indiv.) Rensselaer Polytechnic Institute, Dept. of Architecture, Troy, N. Y.
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O'Reilly, Andrew J. Jr., (Indiv.) 30 Capital Ave., Williston Park, N. Y.
Reynolds, William H. M., (St.) 386 Stuyvesant Ave., Brooklyn, N. Y.
Scheckel, William B., (Indiv.) c/o Voorhees, Walker, Foley & Smith, 101 Park Ave., New York 17, N. Y.

Stadtfeld, Nicolaas T. F., (Indiv.) Division Engineer, Board of Water Supply, 120 Wall St., New York 5, N. Y.
Zwerski, Donald Peter, (St.) 133 E. Seneca St., Sherrill, N. Y.

North Carolina

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Whitehead, Ralph L., (St.) P. O. Box 194, Hobgood, N. C.

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Barrentine, Harry E., (Indiv.) 746 Union Commerce Bldg., Cleveland 14, Ohio
Bentley, Robert, (St.) 170 Monroe St., Warren, Ohio
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Cunningham, John W., (Jr.) 1534 20th St., Cuyahoga Falls, Ohio
Fallon, William Winkler, (St.) 1824 Roxbury Rd., Columbus 12, Ohio
Fosdick, Cedric E., (Indiv.) 5263 Eastern Ave., Cincinnati 26, Ohio
Fostoria Concrete Products, Inc., (Corp.) Sandusky St., Fostoria, Ohio (Arthur Miller, Jr.)
Gaddy, J. W., (Indiv.) North Third & Logan Sts., Steubenville, Ohio
Hollyfield, John B., (Indiv.) 635 E. 185th St., Cleveland 19, Ohio
McDonald, Emmet J., (Indiv.) 265 S. Main St., Akron 8, Ohio
McDowell Company, Inc., (Corp.) 3203 W. 71 St., Cleveland 2, Ohio (Robert C. McDowell, President)

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Mehta, Yoginder Kumar, (Jr.) 1062 Adams St., Corvallis, Ore.
Murphy, Patrick, (St.) 6424 N. Haight Ave., Portland 11, Ore.
Tucker, Stanley, (Indiv.) Route No. 2, Freewater, Ore.
Wong, Homer S., (Indiv.) 1730 S. E. 33rd Ave., Portland 15, Ore.

Pennsylvania

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Conrath, Joseph George, (Indiv.) 439 E. 6th St., Erie, Pa.
Daley, W. E., (Indiv.) District Manager, Sweets Steel Co., 1616 Walnut St., Philadelphia 3, Pa.
Gigliotti, Joseph Anthony, (St.) 4602 Princeton Ave., Philadelphia 35, Pa.
McKnight, James W., (Indiv.) 109 Marlin Drive W., Mt. Lebanon, Pittsburgh 16, Pa.
Senior, Richard L., (Indiv.) 6832 Meade St., Pittsburgh 9, Pa.
Smislova, Alexis, (St.) Lehigh University, Civil Engineering Dept., Bethlehem, Pa.
Wimer, Walter L., (Indiv.) 318 W. Pearl St., Butler, Pa.

South Carolina

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Lott, George Jr., (Indiv.) Box 5185, Columbia, S. C.

Tennessee

Ham, Bert, (Indiv.) Box 412, Tullahoma, Tenn.
McCrodden, Howard J., (Indiv.) 453 E. Drive, Oak Ridge, Tenn.
Peerson, John W., (Indiv.) Chattanooga Bank Bldg., Chattanooga 2, Tenn.

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Pass, Vincent L., (St.) Architectural Bldg. 202, University of Texas, Austin, Texas
Pinnell, Ray A. Jr., (St.) 620 McCullough, San Antonio, Texas

Virginia

Filer, Rowland Franklin Jr., (St.) 1320 Cromwell Rd., Lakewood, Norfolk 5, Va.
McCall, Raymond W., (Indiv.) Box 10-58, South Hill, Va.
Robins, Herbert S., (St.) Virginia Polytechnic Institute, Box A-323, Blacksburg, Va.
Virginia, University of, (Corp.) Dept. of Buildings & Grounds, Charlottesville, Va. (Sylvester H. O'Grince)

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Harrison, William Henry Jr., (Jr.) Pine Bluffs, Wyo.

Hart, Donald Wayne, (Jr.) P. O. Box 24, Lamont, Wyo.
Howard, Clyde Alwyn, (St.) 120 W. 26 St., Cheyenne, Wyo.
Krichbaum, Harrison Henry, (Jr.) 1021 Arapahoe St., Rock Springs, Wyo.
Landgren, George Emmett, (St.) Box 349, Cody, Wyo.
Landgren, John Robert, (St.) 1314 Bleistein, (Box 349), Cody, Wyo.
Read, Robert Arthur, (Jr.) P. O. Box 357, Cheyenne, Wyo.
Rosenblum, Arthur, (Jr.) 2903 Carey Ave., Cheyenne, Wyo.
Schulke, Richard Jewell, (Jr.) 1122 E. 19th Cheyenne, Wyo.
Staats, John Louis, (Jr.) Chugwater, Wyo.

Alaska

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Muir, John M., (Jr.) c/o Water Conservation & Irrigation Comm., Burrinjuck Dam 28, N. S. W., Australia

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Burns, Peter G., (Jr.) Box 340, c/o Hydro-Electric Power Comm. of Ontario, Thessalon, Ont., Canada
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China

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Jackson, Claude L., (Indiv.) Resideat Civil Engineer, Messrs. Kennedy & Donkin, Huncoat Generating Station, Huncoat, Nr. Accrington, Lancashire, England
Preston, Stanley, (Indiv.) 84 Kingsmead Ave., Worcester Park, Surrey, England
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Berroteran, Carlos Santos, (Jr.) c/o SCISP, 6a Ave. Sur No. 54, Guatemala, Gautemala

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Kumar, Anand, (Indiv.) District Engineer, The Concrete Association of India, Sugar Co. Bldg., Bangalore, India

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Kellner, Stefan, (Indiv.) 62 Ussishkin St., Jerusalem, Israel

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Guizar H., Carlos, (Jr.) 1202 Independencia Ave., Chihuahua, Chih., Mexico
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Legaspi, Jesus S., (Indiv.) 56 Horseshoe Str., Cubao, Quezon City, P. I.
Ty, Manuel H., (Indiv.) 558 Caballeros, S. N., Manila, Philippines

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Larrazabal, Gustavo J., (Jr.) Apartado 2970, Caracas D. F., Venezuela
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Mirtolini, Vito, (Indiv.) Avenida Chacaito, Bello Monte, Quinta Nueva, Segovia, Caracas, Venezuela
Muller, Werner Herz, (Indiv.) Urbanizacion Los Caobos, Avenida La Colina, Quinta Glorieta, Caracas, Venezuela
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Otaola, Juan Francisco, (Jr.) Sur 17 No. 31, Caracas, Venezuela
Pardo-Figueredo, Julieta, (St.) Apartado #22, Caracas, Venezuela
Porras-Rodrigo, Julio Cesar, (St.) Blogue 2-EIO, El Silencio, Caracas, Venezuela
Tortosa, Pedro, (Indiv.) Este 12, El Conde, Qta. Yola, Caracas, Venezuela

Tools, Materials, Services

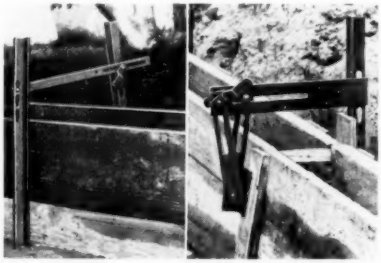
Under this heading note will be made from time to time of producer literature of presumed technical interest (and available from its source for the asking) to ACI users of tools, equipment, materials, accessories and special services.

Form clamps

Adjustable steel clamps for setting up wood forms for curb, curb and gutter and battered curb have been adapted to setting up forms for building foundations. The manufacturer states that the Pacific Boult Clamp is adjustable to any curb and gutter from 4 to 8 in. wide and 24 in. high in general use and for batter of any angle and with a new crossbar can be used for foundations up to 10 in. wide and 36 in. high.

Steel stakes and cross pieces are used and, according to the manufacturer, no special spreaders or wall ties are required and the forms are held rigidly in place without the need of additional bracing except in soft ground. Few nails are required and the face form is supported without stakes.

Further information is available from Pacific Engineering Sales Co., 215 West 5th Street, Los Angeles 13, Calif.



Corrosion-proof cements

The Atlas Mineral Products Co. has released General Bulletin MCC No. 1 which briefly describes Atlas' complete line of chemical construction materials, including corrosion-proof linings, corrosion-proof cements, acid-proof brick and tile, corrosion-proof brick sheathings, corrosion-proof protective coatings and corrosion-proof floors. It also includes handy estimating data. Copies may be obtained from Atlas Mineral Products Co., 42 Walnut St., Mertztown, Pa.

Industrial water engineering

"Let's Consider Your Whole Water Problem," a booklet issued by Hall Laboratories, Inc., discusses industrial water engineering in the fields of water procurement, treatment, usage and disposal. Typical service problems are discussed, with illustrations showing flow schemes of water in process and disposal. Copies are available from Hall Laboratories, Inc., Hagan Bldg., Pittsburgh 30, Pa.

Floor patching

An iron-asphalt patching material for concrete floors is described in an 8-page illustrated bulletin by the Master Builders Co. According to the manufacturer, this material named Masterquick overcomes the problem of early breakdown under impact, particularly of feather edges, encountered with ordinary asphalt patching materials.

The booklet states that the use of scientifically graded, ductile, metallic aggregate in place of brittle aggregates insures a long life patch by overcoming crushing and spreading of repair material, which breaks bond.

The booklet, which also illustrates methods of application of floor patches, can be obtained from Master Builders Co., Cleveland 3, Ohio.

Concrete saw

A portable concrete saw featuring an electric power unit, guide rails and either wet or dry cutting has been developed by Martin Fireproofing Corp. for trimming precast slabs and cutting concrete and asphalt for removal. The manufacturer claims that the electric motor assures a smooth constant flow of power and that the guide rails guarantee a straight clean cut and eliminate cutting blade breakage. The "Creeper" saw can be rolled to the job and handled by one man. Further information may be obtained from Martin Fireproofing Corp., P. O. Box 27, Kenmore Station, Buffalo 17, N. Y.

Pile driving impact

The use of electronic calculating machines in computing pile driving impact is described by Edward A. Smith, Raymond Concrete Pile Co., in a new booklet, "Fundamentals of Electronic Calculation," released by International Business Machines Corp. The article sets up an illustrative problem and the calculations provide a numerical analysis of the behavior of the pile when struck by a pile driving hammer. The results indicated what stresses occurred within the pile and cap block, as well as the penetration of the pile into the earth.

Copies of the booklet are available from International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.

Waterproof paper reinforced with glass

A new waterproof paper called "Glas-Kraft" for use in building construction and concrete curing has been developed which is reinforced with glass fibers. All-directional reinforcement comes from continuous glass fibers swirled between two plies of Kraft and then bonded under heat and pressure. Up to 315 ft of glass yarns go into each square foot of paper.

The manufacturer says that the new paper can be used for vapor barrier, sidewall sheathing and protective floor covering. It may also be used over subfill and for curing concrete floors, sidewalks and pavement. Further information can be obtained from Glas-Kraft, Inc., Lonsdale, R. I.

Industrial research

Arthur D. Little, Inc., has issued an annotated bibliography on "Management of Industrial Research," primarily for use of members of the Arthur D. Little, Inc., staff from the viewpoint of the research direction and of those in charge of research policies. A copy is available to those in this category who may be interested by writing Arthur D. Little, Inc., Cambridge 42, Mass.

Concrete mixers

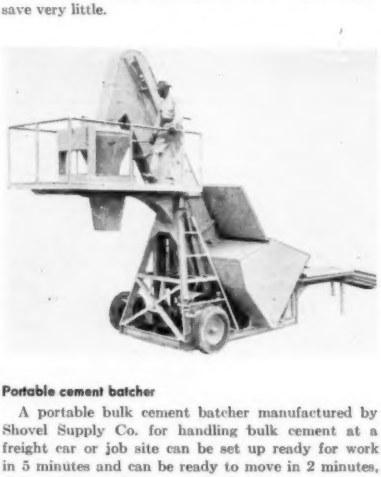
A new bulletin (R-217A) describing Worthington-Ransome Blue Brute concrete mixers, model 11-S and 16-S, is now available from the manufacturer. The bulletin lists the specifications of each mixer and illustrates the various components as well as job operations. Copies of Bulletin R-217A may be obtained from Worthington Pump and Machinery Corp., Ransome Construction Equipment Sales Division, Dunellen, N. J.

Fiberglas insulates floor slabs

Around the 125-ft concrete perimeter of each of the low-cost Levitt homes, mushrooming at Levittown, Long Island, N. Y., sections of Fiberglas slab edge insulation are being laid to block loss of heat through the floor slab edges. The material is being used both as insulation and an expansion joint between slabs and foundation walls.

The insulation consists of 12 x 48 x ¾ in. sections which are set vertically to 12-in. ground depth. When the complete perimeter has been formed, concrete is placed on either side and over the top of the Fiberglas insulation barrier.

In recent years, extensive use of concrete slab floors cast on the ground at grade level has shown the need for cutting heat loss where most of the heat escapes from the floor through the slab edges. These edges are exposed to cold winter air; the earth below the slab is not exposed. Hence, it is claimed, insulation around the edges can save 32 percent of the heat loss from the floor while insulation under the floor would save very little.



Portable cement batcher

A portable bulk cement batcher manufactured by Shovel Supply Co. for handling bulk cement at a freight car or job site can be set up ready for work in 5 minutes and can be ready to move in 2 minutes, claims the manufacturer. The batcher is set up by rotating the elevator around the center pin into working position, retracting the wheels mechanically and setting up ramps for the loading truck. When used at a freight car, ramps are not needed. The batcher will handle up to 12 cu ft per batch, the capacity of a dual-drum paver, and can be controlled by one man. Complete information may be obtained from Shovel Supply Co., Box 1369, Dallas, Texas.

Admixtures and coatings

"15 Steps to Better Concrete Construction," a 12-page illustrated booklet lists detailed information and specifications on Sika compounds used in concrete and masonry construction. It describes the use of Plastiment retarding densifier and 14 additional materials for coating, sealing, hardening and repair work on concrete and masonry. The booklet contains product descriptions and composition, specific uses, contributing properties and architect's specifications. Copies may be obtained from Sika Chemical Corp., 37 Gregory Ave., Passaic, N. J.

Testing machine

Bulletin 310 issued by Baldwin Locomotive Works, describes and illustrates the Model 60-H low-cost universal testing machine. It is built in two separate units, the loading unit and the control unit, with a capacity of 60,000 lb. The booklet describes the loading system, control and lists specifications of the machine. Bulletin 310 can be obtained from the Baldwin Locomotive Works, Testing Equipment Dept., Philadelphia 42, Pa.

Cutting concrete

An 8-page bulletin published by Felker Manufacturing Co. illustrates and discusses the cutting of concrete with diamond abrasive wheels. Concrete cutting machines are described and procedures for cutting and removing concrete are discussed and illustrated. Copies of the bulletin are available from Felker Manufacturing Co., Torrance, Calif.

Form clamps and ties

Specifications for form clamps and ties for securing concrete forms, especially architectural concrete, have been revised by the Williams Form Engineering Corp. These specifications set forth the amount of disconnection recommended for exposed surfaces, and those not exposed; they also recommend types of spacers for architectural concrete, anchor type form aligners, and waler supports. The specifications recommend that the safety factor for ties should be approximately 50 percent greater than pressure conditions designed for.

Copies may be obtained from Williams Form Engineering Corp., 1501 Madison Ave., S.E., Grand Rapids 7, Mich.

Mortar grinder

The Fisher Scientific Co. has issued a leaflet describing their improved mortar grinder. A weighted arm holds the pestle and swings it back and forth in the bowl of the constantly revolving mortar. The manufacturer says that the pattern formed by this double action completely covers the grinding surface. Further information can be obtained from Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

Reconditioning carbide bits

A picture story of interest to crushed stone aggregate producers is presented in a 20-page booklet by Rock Bit Sales and Service Co. It shows how to recondition tungsten-carbide bits and gives many helpful operating suggestions for drillers on how to obtain the maximum speed and footage out of carbide bits. Copies are available from Rock Bit Sales and Service Co., 2514 East Cumberland St., Philadelphia 25, Pa.

Steel scaffold

Tubular steel scaffold is illustrated and described in a leaflet released by Beaver Art Metal Corp. Included in the folder are descriptions of self-contained cam locks for attaching cross braces to panels and the stack lock for locking panels together vertically. Various types of standard panels are illustrated. Copies are available from Beaver Art Metal Corp., Advance Scaffold Division, 1277 Factory Ave., Ellwood City, Pa.

Expansion joint filler

The Celotex Corp. describes Flexcell expansion joints in a short booklet which illustrates uses of the product and compares it with ordinary asphalt joints. Flexcell is a premolded fiber joint of cellular nature impregnated with an asphaltic compound. The manufacturer states that it will not extrude when under compression by adjacent concrete slabs and that it re-expands when released from compression. The booklet is available from the Celotex Corp., 120 S. LaSalle St., Chicago 3, Ill.

Form liner

A 4-page leaflet released by the Celotex Corp. illustrates the use of Celotex absorptive form liners. The liner is made in sheets 4 ft x 3 ft x $\frac{3}{4}$ in. The booklet also lists advantages claimed for the form liner. Copies are available from the Celotex Corp., 120 S. LaSalle St., Chicago 3, Ill.

Pneumatic conveying systems

A well-illustrated booklet published by Convair Corp. shows various installations of pneumatic conveying systems. Sixteen different industrial installations are described. The method uses from 1 to 10 psi pressure to carry a continuously smooth flow of bulk materials through the piping system which moves the entire body of air and suspended solids as a fluid mass. Copies of Bulletin No. 103 are available from Convair Corp., Pittsburgh, Pa.

Form system

The Symons Clamp and Manufacturing Co. has issued a bulletin illustrating the Symons system of wall forming and accessories. The system utilizes panels with tie rods anchored at the sides instead of going through the panels. The manufacturer claims that these ties act as spreaders and do away with 75 percent of the bracing required on old type forms. Copies of the bulletin can be obtained from Symons Clamp and Manufacturing Co., 4249 Diversey Ave., Chicago 39, Ill.

Form engineering

Williams Form Engineering Corp. has published a new 54-page catalog which includes photos and details of form accessories as well as tables for the designing of forms, a section on the construction and design of small retaining walls, and a section on rubber control joint strips.

The well-illustrated booklet shows various uses and installations of forms, form anchors and form ties. Copies may be obtained by writing Williams Form Engineering Co., P.O. Box 925, Madison Square Station, Grand Rapids, Mich.

SYNOPSES of recent ACI Papers and Reports

Institute papers of this JOURNAL Volume 22 are currently available at prices indicated. Please order by title and title number.

SOME OBSERVATIONS ON THE USE OF REINFORCING STEEL IN CONCRETE PAVEMENTS.....47-1

Price 35 cents.

BENGT F. FRIBERG—Sept. 1950, pp. 1-16 (V. 47)

The paper contains a few accumulated observations from a review of literature on the evolution of reinforced concrete pavement designs, with reference to various systems of reinforcement which have seen extended use. Typical structural concrete pavement failures are described. Trends in design and reinforcement practice are shown, with special reference to recent developments. Pertinent findings of a few published pavement surveys are cited, with special attention to the 900-mile Louisiana pavement survey made in 1945. The need for performance information and additional research is stressed.

TESTS OF PAPER MOLDS FOR CONCRETE CYLINDERS.....47-2

Price 35 cents.

ROBERT A. BURMEISTER—Sept. 1950, pp. 17-24 (V. 47)

Concrete test cylinders cast in a new type paper mold had a compressive strength lower than that predicted for the concrete mix used. Investigation showed that cracks and mechanical injuries to the outer shell of the concrete cylinder caused by movement of the paper stock during the first 24 hours of curing reduced the strength of the cylinder. To a lesser degree this was true also of the paraffined paper molds in common use for casting test cylinders, specimens cast in both types of paper molds showing lower strengths than test cylinders from the same mix cast in steel molds.

ADMIXTURES IN CONCRETE.....47-3

Price 60 cents.

W. T. MORAN, F. H. JACKSON, BRUCE E. FOSTER and T. C. POWERS—Sept. 1950, pp. 25-52 (V. 47)

Five papers by members of ACI Committee 212, Admixtures, are, because of their common general subject, presented together.

Various admixtures are discussed briefly as an introduction to more detailed treatment of air-entraining materials. The relative merits of admixtures and interground agents are considered. Optimum ranges of air content for different structural uses are given with particular reference to pavements.

The advantages and disadvantages of several types of admixtures used in the fabrication of various concrete products, such as building block, cast stone, pipe, cribbing and curbing, are discussed. The admixtures considered are classified into the following groups: accelerators, air-entraining agents, gas-forming agents, water repellent agents, and workability agents.

The factors affecting bleeding characteristics and workability of fresh concrete are reviewed and the effect of admixtures on these properties is assessed.

Present knowledge of admixtures in counteracting alkali-aggregate reactions is reviewed. It is emphasized that further studies may revise thinking in this field.

The effectiveness of various concrete admixtures in inhibiting the capillary flow of water and the flow of water under pressure is considered. The types of admixtures included in the discussion are accelerators, soaps, butyl stearate, finely subdivided dry materials, mineral oil, workability agents, and a miscellaneous group of proprietary compounds.

IMPROVED SONIC APPARATUS FOR DETERMINING THE DYNAMIC MODULUS OF CONCRETE SPECIMENS.....47-4

Price 35 cents.

C. E. GOODELL—Sept. 1950, pp. 53-60 (V. 47)

After a brief introduction to sonic testing and a description of commercial equipment, the apparatus built for the Michigan State Highway Department is discussed. Reliable results can be obtained by an unskilled worker with this compact equipment which has twice the frequency band spread of the usual oscillator. A wiring diagram of the sonic apparatus is included.

ANALYSIS OF THREE-DIMENSIONAL BEAM-AND-GIRDER FRAMING.47-5

Price 35 cents.

PHIL M. FERGUSON—Sept. 1950, pp. 61-72 (V. 47)

The beam-and-girder floor with some beams carried directly by columns and others supported on girders is cited as a practical problem in frame analysis that must include the torsional stiffness of the girder. Curves showing how moment coefficients vary with this torsional stiffness are developed for a few simple cases in interior panels. These show the weakness of rule-of-thumb methods.

A practical calculation form is set up for use with the moment distribution method in solving three-dimensional problems of this type.

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DISCUSSION

Discussion closes January 1, 1951

Sept. Jl. '50

Some Observations on the Use of Reinforcing Steel in Concrete Pavements—Bengt F. Friberg

Tests of Paper Molds for Concrete Cylinders—Robert A. Burmeister

Admixtures in Concrete—W. T. Moran, F. H. Jackson, Bruce E. Foster and T. C. Powers

Improved Sonic Apparatus for Determining the Dynamic Modulus of Concrete Specimens—C. E. Goodell

Analysis of Three-Dimensional Beam-and-Girder Framing—Phil M. Ferguson

Revised and amended specifications to conform to recognized developments in concreting practice are proposed for adoption to replace ACI Standard 617-44.

Proposed Revision of

Specifications for Concrete Pavements and Bases (617-44)*

Reported by ACI Committee 617

H. F. CLEMMER
Chairman

T. J. KAUER
A. T. GOLDBECK
FRED HUBBARD
M. ALLAN WILSON
FRANK H. JACKSON
BAILEY TREMPER
STANTON WALKER
W. E. HAWKINS

SYNOPSIS

New specifications incorporated include those covering air entrainment, removal of forms, premolded joint fillers and joint filling materials and method of placing reinforcement. Definitions have been added under soil foundation preparation and other parts of this section have been revised.

SCOPE

1. Concrete pavement and base

These specifications apply to the construction of portland cement concrete pavement and base under normal conditions, including the preparation of the subgrade, and shall govern unless modified by special provisions to take into account unusual conditions of traffic, subgrade, drainage, exposure and other factors.

MATERIALS

2. Approval of sources of material supply

Portland cement, aggregates and water shall be furnished only from sources of supply approved by the engineer before shipments are started. The basis of approval of such sources shall be the ability to produce materials of the quality and in the quantity required.

*Title No. 47-6 is a part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 22, No. 2, Oct. 1950, *Proceedings* V. 47. Separate prints are available at 60 cents each. **Discussion** (copies in **triplicate**) should reach the Institute not later than Feb. 1, 1951. Address 18263 W. McNichols Rd., Detroit 19, Mich.

This report was approved in form and substance as here submitted by the following members of the committee: H. F. Clemmer, T. J. Kauer, A. T. Goldbeck, Fred Hubbard, M. Allan Wilson, Frank H. Jackson, Bailey Tremper, Stanton Walker and W. E. Hawkins. It is released by the Standards Committee for publication and discussion with view to its consideration for adoption at 47th Annual Convention, San Francisco, Feb. 20-22, 1951.

3. Portland cement

(*a*) Cement shall conform to the requirements of the current American Society for Testing Materials Standard Specifications for Portland Cement (Designation C 150) or for Air-Entraining Portland Cement (Designation C 175). The Engineer shall designate the type of cement which is required.

(*b*) Cement shall be protected from the weather and against loss in handling or in transit. Either package or bulk cement may be used.

4. Aggregates

(*a*) Aggregates shall conform to the requirements of the current A.S.T.M. Standard Specifications for Concrete Aggregates (Designation C 33) as amplified by the insertion of limitations in the blanks provided, to meet local conditions.

Coarse aggregate shall be furnished in two separate sizes with the separation at the ¾-in. sieve when combined material graded from No. 4 to 1½ in. is required and at the 1-in. sieve when combined material graded from No. 4 to 2 in. is required.

(*b*) Aggregates shall be so stored as to prevent the inclusion of foreign material. Aggregates shall not be placed upon the finished subgrade. Aggregates of different kinds and sizes shall be placed in different stock piles. Stock piles of coarse aggregates shall be built up in successive horizontal layers not more than 3 ft thick. Each layer shall be completed before the next is started. Should segregation occur, the aggregates shall be remixed to conform to the grading requirements.

(*c*) Frozen aggregates or aggregates containing frozen lumps shall be thawed before use. Washed aggregates and aggregates produced or manipulated by hydraulic methods shall be allowed to drain for at least twelve hours before use. Stock piles or cars and barges equipped with weep holes are considered to offer suitable opportunity for drainage.

5. Water

Water used in mixing or curing concrete shall be clean and free from injurious amounts of oil, salt, acid, vegetable or other substances harmful to the finished product. Sources of water shall be maintained at such a depth, and the water shall be withdrawn in such a manner (by enclosing pump intake, etc.), as to exclude silt, mud, grass or other foreign materials.

6. Reinforcement steel and accessories

(*a*) *Steel wire fabric*—Steel wire fabric reinforcement shall conform to the requirements of the current A.S.T.M. Standard Specifications for Welded Steel Wire Fabric for Concrete Reinforcement (Designation A 185).

(*b*) *Bar mats*—The steel in bar mats shall conform to the requirement of the current A.S.T.M. Standard Specifications for Bar or Rod Mats for Concrete Reinforcement (Designation A 184). Members shall be of the size and spacing shown on the plans. All intersections of longitudinal and transverse bars shall be securely wired, clipped or welded together.

(*c*) *Dimensions of wire fabric and bar mats*—The width of fabric sheets or bar mats shall be such that, when properly placed in the work, the extreme longitudinal members of the sheet or mat will be located not less than 3 in. nor more than 6 in. from the edges of the slab. The length of fabric sheets or bar mats shall be such that, when properly placed in the work, the reinforcement will clear all transverse joints by not less than 2 in. nor more than 4 in. as measured from the center of the joint to the tip ends of the longitudinal members of the sheet or mat.

(*d*) *Bars*—Reinforcement bars shall conform to the requirements of the current A.S.T.M. Standard Specifications for Billet-Steel Bars for Concrete Reinforcement (Designation A 15) or for Rail-Steel Bars for Concrete Reinforcement (Designation A 16). Bars depending upon bond for their effectiveness shall be free from excessive rust, scale, or other substances which prevent the bonding of the concrete to the reinforcement.

(*e*) *Tie bars*—Tie bars shall be deformed steel bars conforming to the requirements of the specifications for reinforcement bars except that rail steel bars shall not be used where they are to be bent and restraightened.

(*f*) *Dowels and sleeves*—Dowels shall be plain round bars conforming to the requirements of the specifications for reinforcement bars. Dowel bars shall not be burred, roughened or deformed out of round in such a manner as to affect slippage in the concrete.

When metal sleeves are used, they shall cover the ends of the dowels for not less than 2 in. nor more than 3 in. The sleeve shall be closed at one end. It shall have a suitable stop to hold the end of the bar at least 1 in. from the closed end of the sleeve. It shall be of such rigid design that the closed end will not collapse during construction.

(*g*) *Chairs*—Chairs for holding tie rods in correct position while the concrete is being placed shall be of metal, slightly rounded and tapered at one end. The minimum dimensions shall be: Thickness 16 gage (U. S. Standard Gage, 1893), length 12 in., width $1\frac{3}{4}$ in. measured along the metal.

(*h*) *Stakes*—Stakes used to support expansion joint fillers shall be channel- or U-shaped, at least $\frac{3}{4}$ in. wide and $\frac{3}{8}$ in. deep and of metal not thinner than 16 gage (U. S. Standard Gage, 1893). They shall be 15 in. long or longer if required to provide proper bearing support.

7. Subgrade paper

Paper to be placed on the soil base shall conform to the requirements of the current American Association of State Highway Officials Standard Specification for Subgrade Paper, M 74.

8. Expansion joint filler

Expansion joint filler shall conform to the requirements of the current A.S.T.M. Specifications for Preformed Expansion Joint Fillers for Concrete D 544.

9. Metal joint plate and pins

Plates for tongue and groove joints shall be steel or iron not thinner than 16 gage, (U. S. Standard Gage, 1893). Each section shall be a continuous

strip of metal not more than 15 ft long having a width ½ in. less than the depth of the pavement; it shall be provided with an end connection which will hold the ends of strips firmly together. Each section shall be of the specified cross section, and shall be punched for dowels or tie bars, and pins, as shown on the plans.

Pins shall be channel shaped, pressed out of sheet steel of not less than 12 gage (U. S. Standard Gage, 1893) and not less than 15 in. long.

10. Cover materials for curing

(*a*) *Burlap*—Burlap shall be made from jute or hemp and, at the time of using shall be in good condition, free from holes, dirt, clay, or any other substance which interferes with its absorptive quality. It shall not contain any substance which would have a deleterious effect on the concrete. Burlap shall be of such quality that it will absorb water readily when dipped or sprayed and shall weigh not less than 7 oz per sq yd when clean and dry. Burlap made into mats may be used if care in handling is exercised to avoid marring the finished surface of the concrete.

(*b*) *Cotton mats*—Cotton mats for curing concrete shall conform to the requirements of the current AASHO Standard Specifications for Cotton Mats for Curing Concrete Pavements. (Designation M 73).

TESTS OF MATERIALS

Materials shall be tested in accordance with methods referred to in the appropriate specifications, except as otherwise specified.

11. Flexural strength tests of concrete as basis of design

Specimens for flexural strength tests to be used as the basis for the design of concrete mixtures shall be molded and cured in accordance with the current A.S.T.M. Standard Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Laboratory (Designation C 192). Specimens shall be tested in accordance with the current A.S.T.M. Standard Method of Test for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading), (Designation C 78).

12. Flexural strength tests of concrete for field control

(*a*) Flexural tests of concrete specimens molded and cured in the field shall be made, whenever feasible, using the testing machine described in A.S.T.M. Method C 78. Results of tests of field cured specimens should not be used as a basis for design of mixtures. If another type of testing machine is used, results obtained with it should be correlated with those obtained from the standard apparatus. Apparatus for making flexure tests of concrete shall be so designed as to incorporate the following principles:

(1) The distance between supports and points of load application shall remain constant for a given apparatus.

(2) The load shall be applied normal to the loaded surface of the beam and in such a manner as to avoid eccentricity of loading.

(3) The direction of the reactions shall, at all times during a test, be parallel to the direction of the applied load.

(4) The load shall be applied at a uniform rate and in such a manner as to avoid shock.

(5) The ratio of distance between point of load application and nearest reaction to the depth of the beam shall not be less than one.

Note: The directions of loads and reactions may be maintained parallel by judicious use of linkages, rocker bearings and flexure plates. Eccentricity of loading can be avoided by use of spherical bearings.

(*b*) *Molding, curing and marking*—Concrete for the field test specimens shall be secured in accordance with the current A.S.T.M. Method of Sampling Concrete (Designation C 172) from the concrete deposited on the subgrade. The specimens shall be molded, finished and cured as described in the current A.S.T.M. Method of Making and Curing Concrete Compression and Flexure Tests in the Field (Designation C 31). Specimens shall be tested in accordance with the current A.S.T.M. Standard Method of Test for Flexural Strength of Concrete (Laboratory Method Using Simple Beam with Third-Point Loading), (Designation C 78). They shall be cured, as nearly as practicable, in the same manner as the pavement concrete. They shall be properly identified as to date of molding and location of pavement represented; weather conditions prevailing at the time of molding shall be noted.

(*c*) *Number of specimens*—At least two beams shall be made for each 1000 sq yd of pavement.

13. Specific gravity and absorption of aggregates

(*a*) *Fine aggregate*—The bulk specific gravity and absorption of fine aggregate shall be determined in accordance with the current A.S.T.M. Standard Method of Test for Specific Gravity and Absorption of Fine Aggregates. (Designation C 128).

(*b*) *Coarse aggregate*—The bulk specific gravity and absorption of coarse aggregate shall be determined in accordance with the current A.S.T.M. Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate (Designation C 127).

14. Consistency

Consistency shall be determined in accordance with the current A.S.T.M. Standard Method of Slump Test for Consistency of Portland Cement Concrete (Designation C 143).

15. Air content

The air content of plastic concrete shall be determined in accordance with current A.S.T.M. Standard Methods of Test for Air Content: (1) Gravimetric (Designation C 138), (2) Volumetric (Designation C 173) or (3) Pressure Method (Designation C 231).

PROPORTIONS OF MATERIALS

16. Basis of Proportions

The proportions of water, cement and aggregates shall be in accordance with *Proportions based on design for minimum strength* (Section 18) or in accordance with *Proportions based on uniform cement factor* (Section 19) as specified in the special provisions.

17. Air content

When concrete is made with an air-entraining cement or air-entraining admixture, the percentage of air shall be maintained between 3-6 percent as determined by methods stated under Section 15 of these specifications.

18. Proportions based on design for minimum strength

(*a*) The proportions of cement, fine aggregate, coarse aggregate and water to be used in the mix shall be determined by the Engineer, within the limits of Sections 18(*b*) and 18(*c*), by means of laboratory tests of the flexural strength of concrete made with aggregates from the same sources and of the same gradings as will be employed in the work and that portland cement which is found to produce the lowest strength concrete of any acceptable cement available for the work.

(*b*) The mixture determined upon shall produce workable concrete having a slump of 2 in. to 3 in. for unvibrated concrete, or ½ in. to 1½ in. for vibrated concrete, and a modulus of rupture at 14 days of not less than 550 psi as determined from specimens made, cured and tested in accordance with the current A.S.T.M. Method C 78.

(*c*) The resulting proportions shall be such that the mixing water, including free surface moisture on the aggregates but exclusive of moisture absorbed by the aggregates, shall not exceed 6 gal. per sack of cement for any individual batch in localities where the concrete will be subjected to severe freezing and thawing conditions. In no case shall the mixing water exceed 6½ gal. per sack of cement for any individual batch. The cement content shall be not less than 5 sacks per cu yd.

(*d*) Unless otherwise specified in the special provisions the following requirements shall govern the contractural relations concerning proportions based on design for minimum strength:

(1) Upon request, the Engineer will furnish prospective bidders with information as to the proportions by weight required for aggregates from established sources available for use on the project. This information will also include the grading of the aggregates used in determining these proportions.

(2) Promptly after receipt of notice of award of the contract, the Contractor shall furnish the Engineer with the location, or locations of the source or sources of aggregates which he proposes to use. The proportions will be designated by the Engineer. Except as hereinafter provided the designated proportions shall govern as long as materials are furnished from the sources designated and as long as they continue to meet the requirements specified.

(3) If, during the progress of the work, the Contractor proposes to use aggregates from approved sources other than those originally designed, the Engineer will designate the new proportions to be used.

(4) If satisfactory plasticity and workability are not secured using the proportions and aggregates originally designated, the Engineer may alter such proportions. If such alterations change the designated cement factor originally fixed by 2 percent or less, no adjustment in the amount paid the Contractor shall be made. If such alterations change the designated cement factor by more than 2 percent, the source and quality of the aggregates remaining the same, payment shall be adjusted for or against the Contractor in whatever amount the total cost of materials, f.o.b. Contractor's material yard, has been increased or decreased by more than 2 percent. The calculation of the amount of such increase or decrease shall be based upon the designated cement factor and not on count of bags of cement used or of the batches where bulk cement is used.

TABLE 1—PROPORTIONS BASED ON A FIXED CEMENT CONTENT AND SPECIFIED SLUMP*

Specification requirements					Quantities of materials to be used for proportioning trial batches			
						Pounds of aggregates per 94-lb bag of cement††		
Type of concrete**	Method of placing	Type of coarse aggregate†	Range in slump, in.	Cement, bags per cu yd‡	Water, gal. per bag	Fine aggregate§	Coarse aggregates	
							Small	Large
Plain	Machine	Gravel	2-3	6.0	5.0	175	140	215
Plain	Machine	Crushed stone	2-3	6.0	5.6	200	130	200
Plain	Machine	Slag	2-3	6.0	5.9	210	110	160
Plain	Vibrated	Gravel	1-1½	5.5	5.0	175	170	255
Plain	Vibrated	Crushed stone	1-1½	5.5	5.6	200	160	240
Plain	Vibrated	Slag	1-1½	5.5	5.9	210	130	200
Air-ent.	Machine	Gravel	2-3	6.0	4.5	155	140	215
Air-ent.	Machine	Crushed stone	2-3	6.0	5.1	180	130	200
Air-ent.	Machine	Slag	2-3	6.0	5.3	190	110	160
Air-ent.	Vibrated	Gravel	1-1½	5.5	4.5	155	170	255
Air-ent.	Vibrated	Crushed stone	1-1½	5.5	5.1	180	160	240
Air-ent.	Vibrated	Slag	1-1½	5.5	5.1	190	130	200

*Aggregate weights are based on assumed bulk specific gravity of 2.65 for sand, gravel and crushed stone and 2.25 for slag, all in saturated, surface dry condition. For aggregates having other specific gravities, the desired weights equal tabulated weights of respective materials, divided by the assumed specific gravities multiplied by the actual specific gravities of the materials to be used.

†Coarse aggregates are 1½ in.-No. 4 or 2 in.-No. 4 and graded approximately 40 percent small and 60 percent large separated on the ¾ in. or 1 in. sieve, respectively.

‡Compliance with this requirement shall be determined by means of a yield test made in accordance with A.S.T.M. Standard Method C 138. If the cement content calculated from this test varies from the designated cement content by more than 2 percent, the total weight of aggregate per bag of cement shall be adjusted as necessary to bring the cement content within the specified limits.

§Fine aggregate proportions are based on the use of well graded natural sand of 2.75 fineness modulus.

**Air content is assumed as 1 percent for plain mixes and 4 percent for air-entraining mixes.

††If the aggregates contain more water than required for saturation, the aggregate weights should be increased by the weight of surface water present; if they contain less water than required for saturation, the weights should be decreased by the amount in weight of water necessary to attain saturation of aggregate. Free water on aggregates should be accounted as a part of the mixing water.

19. Proportions based on fixed cement content

When concrete having a fixed cement content is specified, the quantities shall be those given in Table 1 properly adjusted to compensate for differences in specific gravities. Upon approval by the Engineer, these compensated quantities of materials shall be further adjusted by the Engineer at any time to attain the desired degree of workability, the specified slump, and the specified cement content. Batch weights thus determined, shall be corrected to take into account the moisture condition of the aggregates as used.

MEASUREMENT AND HANDLING OF MATERIALS

20. Cement, aggregates, water

(*a*) Standard size sacks of cement as packed by the manufacturer shall be considered to weigh 94 lb net. Bulk cement and cement from fractional sacks shall be weighed.

(*b*) When package cement is used, the cement shall be emptied from the sacks into the batch immediately prior to mixing. When bulk cement is used, satisfactory methods of handling and weighing shall be employed. A separate hopper shall always be so designed and operated that the quantity of cement for each batch will be maintained in a separate container so as not to come in direct contact with the aggregates.

(*c*) Aggregates shall be weighed. Each size of aggregate shall be weighed separately.

(*d*) The scales for weighing cement and aggregates shall be accurate within ½ of 1 percent throughout the range of use. Operation shall be within a maximum allowable error of 1 percent for cement and 2 percent for aggregates.

(*e*) Mixing water may be measured by weight or by volume. The water-measuring device shall be accurate to ½ of 1 percent. Operation shall be required to be within a maximum allowable error of 1 percent. When wash water is used as a portion of the mixing water for succeeding batches, it shall be measured according to this requirement.

MIXING

21. Mixing at site or at central mixing plant

(*a*) The concrete shall be mixed in a batch mixer. When a drum mixer is used, it shall conform to the requirements of the concrete mixer standards of the Mixer Manufacturers Bureau of the Associated General Contractors of America. If another type of mixer is used, it shall be of a type satisfactory to the Engineer. The mixer shall be capable of combining the aggregates, cement and water into a thoroughly mixed and uniform mass within the specified time, and of discharging the mixture without segregation. Each batch of concrete shall be mixed for one minute or more after all materials, exclusive of the mixing water, are in the mixer drum. The batch shall be so charged into the mixer that some water will enter in advance of the cement and aggregate, and will continue to flow for a period which may extend to the end of the first one-third of the specified mixing time. The mixer shall rotate at the rate recommended by its manufacturer. Concrete shall be mixed only in quantities required for current use; any concrete which has set so that it cannot be placed properly shall not be used. Retempering of concrete which has partially set, by mixing with additional water, will not be permitted.

(*b*) The mixer shall be equipped with a suitable charging hopper, water storage, and a water-measuring device controlled from a case which can be kept locked. Controls shall be so arranged that the water can be started only while the mixer is being charged and so as to lock automatically the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged after each charge has been mixed the required time. In case of mixing at the site suitable equipment for discharging and spreading the concrete on the subgrade shall be provided. The mixer shall be cleaned at suitable intervals. The pick-up and throw-over blades in the drum shall be replaced when they have lost 10 percent of their depth. The volume of the mixed material per batch shall not exceed the manufacturer's normal rated capacity of the mixer, exclusive of the overload. The manufacturer shall install a plate upon the mixer stating the rated capacity and the recommended revolutions per minute.

22. Ready-mixed concrete

Ready-mixed concrete shall be mixed and transported in accordance with the current A.S T.M. Specifications for Ready-Mixed Concrete (Designation C 94).

HIGH-EARLY STRENGTH CONCRETE

23. Methods of production

High-early strength concrete shall be produced by one of the following methods, or any combination thereof, as specified in the special provisions.

(*a*) By the use of high-early strength portland cement Type III in lieu of normal portland cement (Type I or IA or Type II or IIA).

(*b*) By the use of additional portland cement (Type I or IA or Type II or IIA) in which case the total amount of cement shall not exceed 7 bags of cement per cu yd of concrete.

(*c*) By the use of calcium chloride as one of the ingredients of the concrete in an amount between 1 and 2 lb of calcium chloride per sack of cement. Calcium chloride may be added either dry or in solution. When used in solution, it is convenient so to proportion the solution that 1 quart contains 1 lb of calcium chloride.

High-early strength concrete shall meet the requirements of these specifications for portland cement concrete.

The relative value of the above methods for producing early strength is usually in the order stated, beginning with the highest.

SOIL FOUNDATION PREPARATION

24. Grading stakes

Grading stakes shall be protected by the Contractor. Stakes which become disturbed shall be reset at the Contractor's expense.

25. Definitions

The following definitions shall apply in these specifications where applicable:

Embankment foundation—The material on which an embankment is placed.

Embankment (fill)—A raised structure of soil-aggregate or rock.

Subgrade material (Basement soil)—The material in excavations (cuts), and embankments (fills), and embankment foundations immediately below the first layer of subbase, base or pavement and to such depth as may affect the structural design.

Soil subbase—Specified or selected material of planned thickness placed as foundation for a base.

Soil base—Specified or selected material of planned thickness placed as a foundation for a pavement.

Silt-clay (Minus No. 200 material)—Fine soil particles which will pass the No. 200 sieve.

(*a*) *Silt fraction*—Material passing the No. 200 sieve and larger than 0.005 mm.

(*b*) *Clay fraction*—Material smaller than 0.005 mm including colloids which are the particles of the clay fraction smaller than 0.001 mm.

26. Clearing right-of-way

Where fills are less than 10 ft high, all sod, underbrush, trees, tree stumps and saplings shall be grubbed and entirely removed; when fills more than 10 ft high are to be made, the ground shall be cleared of all underbrush, and all trees and saplings shall be cut off not over one foot above the ground.

27. Solid rock

Solid rock (boulder of 1 cu yd or more in content, or ledges in their original bed) shall be removed 6 in. below grade and shall be paid for at the contract price per cu yd of solid rock.

28. Excavated materials

Material excavated in cuts may be used in fills on the job provided the material conforms to the specifications for fill materials contained herein. Excess or unsuitable material shall be disposed of by the Contractor at his expense.

Any excavation of approved soil below the surface of the base as shown on the plans shall be refilled with approved material compacted as provided herein for filling and compaction at the Contractor's expense.

29. Removal of unsuitable material

All unsuitable material shall be removed to a depth of at least 18 in. below the finished surface of the soil base. The contractor will be paid for the work at the prices bid for grading and materials used.

When unsuitable material is removed from the soil base, the surface shall be brought to the correct elevation with approved material placed and compacted as specified herein. Payment for this work will be made at the contract prices for grading and materials.

30. Borrowed material

Borrowed material shall be secured from pits indicated on the plans. If no such location is indicated or the quantity of the material at the pits is insufficient, the Contractor shall furnish material conforming to the requirements of these specifications. Payment shall be made for such material at the price bid for borrow per cu yd.

31. Soil base material

Soil base material shall meet the requirements as specified in the current AASHO Specification for Materials for Stabilized Base Course, M 56.

32. Soil fill material

All material used in earth fills must meet the following specifications and may be rejected on visual inspection pending the testing of samples.

Fill material shall be a well-graded combination of granular material, silt and clay soil. The material shall have a minimum of 80 percent passing the No. 4 sieve, at least 65 percent retained on, and at least 20 percent passing the No. 200 sieve. No gravel or stone shall be larger than one-third the depth of the layer to be placed. The soil shall have a liquid limit, as determined by the current AASHO Method of Determining the Liquid Limit of Soils, T 89, not greater than 35. The material to be used shall be free from trash brick, broken concrete, tree roots, sod, ashes or cinders.

Samples of the fill material will be taken from every 500 cu yd or fraction thereof. Samples will also be taken whenever in the opinion of the Engineer the texture of the material appears to be changing.

Contractors desiring approval of the source of a material shall submit samples at least one week in advance of the desired date of approval. Acceptance of material from any location shall not be construed as approval of the entire location, but only insofar as it continues to meet the specifications.

33. Compaction equipment

Compaction may be accomplished by means of smooth rollers, pneumatic tired rollers, tamping or sheepsfoot rollers. However, the equipment selected shall be capable of compacting the soils to density requirements hereinafter specified.

When compaction is to be accomplished in places inaccessible to rolling, mechanical tampers capable of striking a blow equivalent to at least 250 lb per sq ft shall be used.

34. Consolidation of road foundation

All fills, soil bases, and soil subbases shall be compacted in layers not greater than 6 in. in depth. Each layer shall be compacted to at least an average minimum density requirement expressed as a percentage of the maximum density as determined by the current AASHO Standard Laboratory Method of Test for the Compaction and Density of Soil, T-99. The field density shall not be less than the percentage of the maximum density shown in the following table:

Standard of compaction or maximum density obtained by Method T-99, lb per cu ft	Minimum compaction, required percent of maximum density
90 to 99.9	100
100 to 119.9	95
120 and above	90

35. Payment for grading

The contract prices for grading shall include the cost of excavating and filling, clearing and grubbing, excavating and removing unsuitable materials as required, shaping the subgrade to the prescribed lines and grades, sloping cuts, intersections and approaches, and rolling or tamping below the subgrade in the case of fills; and in connection with street construction, sloping and filling between the curb and sidewalk pavement, and grading and shaping of sidewalk spaces where shown on the plans. Payment shall be made at price bid per cu yd computed to the grades and slopes shown on the plans.

36. Wetting the soil base

Except where subgrade paper is required by the special provisions the soil base shall be thoroughly wetted a sufficient time in advance of the placing of the concrete to insure that there will be no puddles or pockets of mud when the concrete is placed. The degree of saturation shall depend upon the characteristics of materials in the base.

37. Testing and correcting the soil base

Immediately prior to placing concrete, the soil base shall be tested for conformity with the cross section shown on the plans by means of an approved template riding on the side forms. If necessary, material shall be removed or added, as required, to bring all portions of the soil base to the correct elevation. It shall then be thoroughly compacted and again tested with the template. Concrete shall not be placed on any portion of the soil base which has not been tested for correct elevation.

If the soil base is disturbed after acceptance, it shall be reshaped and compacted without additional compensation. Payment for compacting soil base shall be included in the contract prices for grading.

38. Placing subgrade paper

When specified in the special provisions the soil base, after it has been shaped and compacted, shall be covered with subgrade paper. Adjacent strips of paper shall lap 4 in. and ends shall lap 12 in. After being placed on the base, the paper shall be kept reasonably intact and shall not be hauled over nor have unnecessary holes punched through it.

FORMS

39. Material and dimensions

Side forms shall be made of metal having a thickness of not less than $\frac{7}{32}$ in. and shall have a depth equal to the specified edge thickness of the concrete. Building up of forms shall not be permitted. Flexible or curved forms of proper radius shall be used for curves of 100 ft radius or less. Forms shall not deflect more than $\frac{1}{4}$ in. when tested as a simple beam with a span of 10 ft and a load equal to that which the finishing machine or other construction equipment will exert upon them. Forms 8 in. or more in height shall be at least 8 in. wide at the base; forms less then 8 in. in height shall have a base width at least equal to the height of the forms. The flange braces must extend outward on the base not less than $\frac{2}{3}$ the height of the form. The forms shall be free from warp, bends, or kinks. The top of the form shall not vary from a 10 ft straightedge by more than $\frac{1}{8}$ in. at any point and the side of the form by more than $\frac{1}{4}$ in.

40. Base support

The subgrade under the forms shall be compacted and cut to grade so that the forms, when set, shall be uniformly supported for their entire length and at the specified elevations. Subgrade found to be below established grade at the form line shall be filled to grade in lifts of $\frac{1}{2}$ in. or less for 18 in. on each side of the base of the form and thoroughly re-rolled or tamped. Imperfections and variations above grade shall be corrected by tamping or by cutting, as necessary.

41. Grade alignment

The alignment and grade elevations of the forms shall be checked and the necessary corrections made by the Contractor immediately before placing the concrete. When any form has been disturbed or any subgrade thereunder has become unstable, the form shall be reset and rechecked.

42. Staking forms

Forms shall be staked with three or more pins for each 10 ft section. A pin shall be placed adjacent to each side of every joint if required. Form sections shall be tightly joined by a locked joint free from play or movement in any direction. Forms shall be cleaned and oiled prior to the placing of concrete.

43. Advance setting

Forms shall be set for at least 300 ft in advance of the point where concrete is being placed.

44. Removal of forms

Forms shall remain in place at least 12 hours after placing the concrete. If the air temperature is below 50 F at any time during the 12-hour period from the time the concrete is placed, the forms shall not be removed until 36 hours after placing of the concrete, unless high-early strength concrete is being used.

INSTALLATION OF JOINTS AND REINFORCEMENT

45. Joints

(*a*) All longitudinal and transverse joints shall conform to the details and positions shown on the plans.

(*b*) All joints shall be constructed true to line with their faces perpendicular to the surface of the pavement. Joints shall not vary more than ¼ in. from a true line or from their designated position.

(*c*) The surface of the pavement adjacent to all joints shall be finished to a true plane and edged to a radius of ¼ in. or as otherwise shown on the plans. The surface across the joints shall be tested with a 10-ft straightedge as the joints are finished and any irregularities in excess of ⅛ in. shall be corrected before the concrete has hardened.

(*d*) Keyways, when required, shall be accurately formed with templates of metal or wood. The gage, or thickness, of the material in the template shall be such that the full keyway as specified is formed.

46. Longitudinal joints

Longitudinal joints shall be constructed along or parallel to the centerline of the pavement unless othersiwe specified.

(*a*) *Metal keyway joints*—Longitudinal "metal strip" joints shall be formed by installing a metal parting strip of the gage, shape and dimensions shown on the plans, to be left permanently in place. The metal strip shall be held securely in place, true to line and grade by suitable steel pins, which may be either channel shaped or round bars, spaced at intervals that average not less than 3 ft and in no case more than 4 ft. The minimum length of metal strips shall be 10 ft and adjoining sections shall be securely fastened by lapping and pinning, by means of a slip joint, or other approved method. The Contractor shall furnish an approved gage to ride on the side forms for checking the position of the parting strip before concrete is placed against it.

(*b*) *Dummy joints*—Longitudinal "dummy groove" or weakened plane joints shall be formed by a groove or cleft in the top of the slab. The groove shall be ⅜ in. wide at the surface and ¼ in. wide at the bottom unless otherwise specified. It shall be made in the plastic concrete by a suitable tooling device and shall extend vertically downward from the surface to at least ⅓ and not more than ½ the depth of the concrete.

(*c*) *Construction joints*—Longitudinal construction joints (*i.e.*, joints between slabs placed separately) shall be formed by the use of standard steel side forms with keyway, unless otherwise indicated in the plans. Provision shall be made for the installation of tie bars as noted in these specifications, or in the plans or special provisions.

(*d*) *Tie bars*—Tie bars not less than ½ in. diameter and 42 in. long, unless otherwise specified, shall be placed across all longitudinal joints. Tie bars shall be placed at right angles to the centerline and shall be spaced at intervals of 30 in. unless otherwise shown on the plans. They should be held in a position approximately parallel to the transverse axis of the pavement and midway between the top and bottom surfaces of the slab. Tie bars may be bent at right angles against the form at longitudinal construction joints, unless threaded bolt or other assembled tie bars are specified.

47. Expansion joints at structures

Expansion joints shall be formed about all structures and features projecting through, into, or against the pavement. Unless otherwise indicated on the plans, such joints shall be not less than ¼ in. thick and shall be of the premolded type.

48. Transverse expansion joints

Transverse expansion joints shall be constructed at right angles to the centerline of the pavement, unless otherwise required, and shall extend the full width of the pavement.

(*a*) *Premolded expansion joints*—Transverse premolded expansion joints shall be formed by securely staking an approved "installing bar" or installing device perpendicular to the proposed surface of the pavement. The installing bar shall be of substantial metal plate and shall have a length ½ in. less than the required width of the slab and shall be cut to the required depth and crown of the slab. It shall be securely staked in position so that the top edge, unless otherwise provided on the plans, will be uniformly ¼ in. below the pavement surface. The lower edge shall be cut to conform to the prescribed cross section of the subgrade. The installing bar shall be slotted from the bottom as necessary to permit the installtion of the required dowels. Suitable means shall be provided on the bar for facilitating its removal. Header boards, sheet metal holders or other devices used in lieu of the installing bar shall be subject to approval by the Engineer. The joints shall be protected against damage until they are installed in the work. Joints damaged during transportation, or by careless handling, or while in storage shall be replaced or repaired by the Contractor. Repaired joints shall not be used until they have been approved by the Engineer.

(*b*) *Premolded joint filler*—The designated premolded joint filler shall be appropriately punched to the exact diameter and at the locations of the dowels. It shall be furnished in lengths equal to one-half the designated width of the slab. Where more than one section is used in a joint, they shall be securely placed or clipped together. The premolded joint filler shall

be placed on the side of the "installing bar" nearest the mixer. The bottom egde of the filler shall extend downward to or slightly below the bottom of the slab, and the top edge, unless otherwise prescribed, shall be held about ½ in. below the surface of the pavement in order to allow the finishing operations to proceed continuously. The top edge of the filler shall be protected while the concrete is being placed, by a metal channel cap of at least 10 gage material, having flanges not less than 1½ in. deep. The installing device may be designed with this cap self-contained.

49. Transverse contraction joints

(*a*) *Metal strip type*—Transverse "metal strip" contraction joints shall be formed during the placing of the concrete by installing a metal parting strip to be left in place. This strip shall conform to the requirements for type, gage, shape, and dimensions shown on the plans or indicated in the special provisions and shall be securely staked in place. This strip shall be temporarily capped with a metal channel cap. The dowel assembly and the method of placing it shall be as indicated for transverse expansion joints, except that sleeves or caps on dowels will not be required. Concrete shall be deposited as for transverse expansion joints. After the longitudinal floating has been completed but before the surface is finished, the metal cap shall be removed and the concrete edged, and the joint sealed as required for expansion joints.

(*b*) *Weakened plane type*—Transverse joints of the weakened plane or "dummy" type shall be constructed in a manner similar to that provided for dummy joints for longitudinal joints, except that such joints shall be provided with slip dowels or other load transfer devices of the type ,size, and arrangement shown on the plans.

50. Weakened plane warping joints

Weakened plane warping joints, when specified, shall be constructed in the locations shown on the plans and in the same manner as the weakened plane contraction joints, except that the load transfer devices shall be omitted and the pavement reinforcing shall extend through the joint.

51. Transverse construction joints

Unless other prescribed joints occur at the same points, transverse construction joints shall be made at the end of each day's run or where interruption of more than 30 minutes occur in the concreting operations.

Transverse construction joints shall not be formed so as to make a slab less than 10 ft in length and if sufficient concrete is not mixed to form a slab at least 10 ft in length, the joints shall be formed at the preceeding joint location and the excess concrete disposed of as directed by the Engineer.

The spacing of subsequent transverse joints shall be measured from the transverse construction joint last placed.

52. Transverse weakened plane joints—base course

Concrete bases shall be provided with expansion and or contraction joints, and shall be constructed in accordance with provisions of these specifications for constructing similar joints in concrete surface courses.

Note: For bases it is especially important to reduce the interval between joints by means of closely spaced contraction joints so as to control the amount of joint opening (which may extend through the surface course) due to shrinkage and contraction. Experience indicates that the best results are obtained when the spacing of such joints does not exceed 20 ft. Preferably the spacing should not exceed 15 ft.

53. Load transfer devices

(*a*) Dowel bars at least ¾ in. in diameter, 16 in. long, spaced at 12 in. center to center, or other approved type of load transfer device shall be placed across all transverse joints, except warping joints, in the manner shown on the plans. Dowels shall be placed at the middle of the slab depth and held rigidly in proper horizontal and vertical alignment by an approved dowel assembly device to be left permanently in place. A tolerance of not more than 1 in 48 from the correct alignment will be permitted.

(*b*) Dowel coating. The free or unbonded end of each dowel shall be painted with one coat of red lead or basic sulfate blue lead paint at the site of the work. When the paint has dried, the free end of each bar shall be thoroughly coated with heavy oil immediately before it is placed in position. The free end of the dowel bars across expansion joints shall be provided with a metal dowel sleeve conforming to the dimensions shown on the plans, or as approved by the Engineer.

54. Installation of joints

(*a*) If the paving mixer is operated from the shoulder, the joints shall be set immediately after the final testing of the subgrade. If the paving mixer is operated from the subgrade, the joints shall be set immediately after it moves forward, so as to permit as much time as possible for proper installation.

(*b*) The assembled joint shall be put in place on the prepared subgrade. It shall be placed at right angles to the centerline of the pavement. The top of the joint shall be set at the proper distance below the pavement surface and the elevation checked by a properly designed templet. On widened curves, the longitudinal center joint shall be placed so that it will be, as nearly as possible, equidistant from the edges of the slab. The joint shall be set to the required line and grade and shall be securely held in the required position by stakes or an approved installing device or both during the placing and finishing of the concrete. Joints shall be installed so that the concrete pressure will not disturb their alignment. The joints shall be vertical and no joint shall deviate more than ¼ in. in horizontal alignment either way from a straight line. If joints are constructed in sections, there shall be no offsets between adjacent units. Dowel bars shall be checked for exact position and alignment as soon as the joint is staked in place on the subgrade and the joint shall be tested to determine whether it is firmly supported. Any joint not firmly supported shall be reset.

55. Joint fillers

(*a*) Joint filler and material for sealing joints shall conform to the requirements of the specifications and special provisions.

(*b*) The top of expansion joints and all edged joints shall be sealed with the specified filler before traffic is permitted on the pavement. The joint opening shall be thoroughly cleaned of all foreign matter before the sealing material is placed. All contact faces of the joint shall be cleaned with a wire brush to remove loose material, and shall be surface dried when the filler is poured.

(*c*) The filler shall be poured into the joint opening to conform to the details shown on the plans or as directed by the Engineer. The pouring shall be done in such a manner that the material will not be spilled on the exposed surfaces of the concrete. Any excess filler on the surface of the concrete pavement shall be removed immediately and the pavement surface cleaned.

(*d*) When required to prevent tackiness or pickup under traffic, the exposed surfaces of the filler shall be dusted with hydrated lime. Other methods of preventing pickup under traffic may be used when approved by the Engineer.

(*e*) Poured fillers shall not be placed when the air temperature in the shade is less than 50 F except by the approval of the Engineer.

56. Placing reinforcement

(*a*) Steel reinforcement shall consist of welded wire fabric or bar mats in accordance with Section 6 of these specifications. Reinforcing steel shall be free from dirt, scale, or other foreign matter, and rust of such degree of development as to impair bond of the steel with the concrete.

(*b*) When bar assemblies are shown on the plans, the reinforcement bars shall be firmly fastened together at all intersections. Adjacent ends shall lap not less than 30 diameters.

(*c*) Where bars are fabricated into mat form by positive welding at all intersections, the lap may be of such length as will permit cross bars to overlap each other by at least 2 in. The same requirements apply to end laps and side laps.

(*d*) Steel fabric sheets shall be lapped and shall clear all edges of the slab, as shown on the plans. Where steel fabric is used, the concrete shall be struck off by means of a template at the indicated depth of the reinforcing below the finished surface of the slab.

(*e*) Reinforced concrete shall be placed in two operations. The initial pour shall be uniformly struck off 2 in. below the proposed surface of the pavement unless otherwise shown on the plans, and the reinforcement placed thereon. The concrete shall be struck off to the entire width of the pour and a sufficient length to permit the sheet or mat of reinforcement to be laid full length on the concrete in its final position as shown on the plans, without further manipulation of the reinforcement. Adjacent sheets shall be lapped as provided on the plans. The balance of the required concrete shall be placed on the reinforcement. Displacement of the reinforcement during concrete operations shall be prevented.

PLACING AND FINISHING CONCRETE

57. General

(*a*) Concrete shall be distributed to such depth, above grade, that when consolidated and finished, the specified slab thickness will be obtained at all points and the surface will not be below the grade specified for the finished surface at any point.

(*b*) The concrete shall be deposited on the subgrade in such manner as to require as little rehandling as possible. It shall be thoroughly consolidated against and along the faces of the worms. Necessary hand spreading shall be done with shovels, not with rakes. Workmen shall not be allowed to walk in the concrete with boots or shoes covered with earth or other foreign substances.

(*c*) Concrete shall be placed only on subgrade which has been prepared as specified and approved. At all times during operations, at least 300 ft of subgrade shall have been prepared ahead of the mixer. Concrete shall not be placed on a frozen subgrade. No concrete shall be placed around manholes or other structures until they have been brought to the required grade and alignment.

(*d*) Pavement less than 30 ft wide may be constructed either to its full width in a single construction operation or in lanes, unless one or the other method is expressly stipulated on the plans. Pavement more than 30 ft wide shall not be constructed in a single operation. When pavement is constructed in separate lanes, the junction line shall not deviate from the true line shown on the plans by more than ½ in. at any point.

(*e*) Retempering concrete by adding water or by other means will not be permitted.

58. Placing and finishing concrete at joints

(*a*) Concrete shall be deposited on the subgrade as near to the expansion and contraction joints as possible without touching them. It shall then be shoveled against both sides of the joint simultaneously, maintaining equal pressure on both sides. It shall be deposited to a height of approximately 2 in. more than the depth of the joint, care being taken that it is worked under the load transfer devices. The concrete shall not be dumped from the discharge bucket of the mixer directly upon or against the joints, nor shall it be shoveled or dropped directly on top of the load transfer devices. In placing the concrete against expansion and contraction joints and in operating a vibrator adjacent to them, workmen shall avoid stepping upon or disturbing in any way the joints or load transfer devices, either before or after they are covered with concrete.

(*b*) The concrete adjacent to the joint shall be compacted with a vibrator inserted in the concrete and worked along the entire length and on both sides of the joint. The vibrator shall not come in contact with the joint, the load transfer devices, or the subgrade. If any of the dowel bars are displaced, they shall be realigned before the finishing machine passes over them.

(*c*) After the concrete has been vibrated, the finishing machine shall be moved forward until the front screed is approximately 8 in. from the joint. Segregated coarse aggregate shall be removed from both sides of and off the joint. The screed shall be lifted and brought directly above the joint, set upon it, and the forward motion of the finishing machine shall be resumed. When the second screed is close enough to permit the excess mortar in front of it to flow over the joint, it shall be lifted and carried over the joint. Thereafter, the finishing machine may be run over the joint without lifting the screeds, provided there is no segregated coarse aggregate immediately between the joint and the screed or on top of the joint.

(*d*) After the concrete has been placed on both sides of the joint and struck off, the installing bar or channel cap shall be slowly and carefully withdrawn leaving the premolded filler in place. After the installing bar or channel cap is completely withdrawn the concrete shall be carefully spaded and additional freshly mixed concrete worked into any depressions left by the removal of the installing bar. The installing bar shall be cleaned and reoiled prior to each installation of a joint.

Immediately after all finishing operations, including brooming, have been completed and before the concrete has taken its initial set, it shall be edged adjacent to all expansion and contraction joints. Care shall be used to remove any concrete which may be over the premolded joint material. The edging tool shall be so manipulated that a well-defined, continuous radius is produced and a smooth, dense mortar finish obtained. The edging tool shall not be tilted while being manipulated.

After the removal of the side forms, the ends of premolded transverse joints at the edges of the pavement shall be carefully opened for the entire depth of the slab, and in the case of air cushion joints any concrete that has been deposited over the end closure shall be removed, care being taken not to injure the ends of the joint. After the curing period and before the pavement is opened to traffic, premolded joints shall be sealed or topped out, leaving a neat uniform strip of an approved filler material.

59. Finishing methods

(*a*) *Machine finishing*—The concrete as soon as placed shall be struck off and screeded by an approved finishing machine to the crown and cross section shown on the plans and to an elevation slightly above grade that so when properly consolidated and finished the surface of the pavement will be at the exact grade elevation indicated on the plans and free from porous places. The finishing machine shall be of the screeding and troweling type, equipped with two independently operated screeds, designed and operated to strike off the concrete. The machine shall go over each area of pavement as many times and at such intervals as is necessary to give the proper compaction and to leave a surface uniform texture, true to grade and crown. Excessive operation over a given area shall be avoided. The last trip for a given area shall be a continuous run of at least 40 ft. The tops of the forms shall be kept clean by an effective device attached to the machine and the travel of the

machine on the forms shall be maintained true without lift, wobbling, or other variation tending to affect the precision of finish. The finishing machine shall be of ample strength to withstand severe use and shall be fully and accurately adjustable for loss of crown or other derangement due to wear.

During the first pass of the finishing machine a uniform ridge of concrete at least 3 in. deep shall be maintained ahead of the front screed for its entire length. Except when making a construction joint, the finishing machine shall not be operated beyond that point where the above described surplus can be maintained ahead of the front screed.

(*b*) *Vibrated finishing*—When vibrated finishing is required by the special provisions, the finishing machine shall be equipped for applying high-frequency vibration to the upper surface of the concrete in accordance with the requirements for either of the following types. The particular type selected by the Contractor shall be subject to approval of the Engineer. The vibratory units shall be synchronized and shall operate at a frequency of not less than 3500 cycles per minute.

1. *Vibrating units mounted directly on the screeds*—This type shall consist of two independently operated screeds. The front screed shall be equipped with not less than one vibrating unit for each 7½ ft length or portion thereof of vibratory screed. The front screed shall be not less than 15 in. wide and shall be equipped with a bull-nose front edge having a radius of not less than 2 in.

2. *Vibrating pan mounted independently of the screeds*—This type shall consist of two independently operated screeds together with an independently operated vibratory pan (or pans). The pan shall be mounted in such a manner as not to come in contact with the forms. It shall rest directly on the concrete and shall be so adjusted as to produce uniform vibration over the entire width of pavement surface. The pan shall be equipped with not less than one unit for each 7½ ft of length or portion thereof of vibrating pan. The screeds shall be capable of operating in a position that will strike off the concrete at a sufficient height above the top of the forms to allow for proper compaction with the vibratory pan.

(*c*) *Floating*—As soon as possible, after the concrete has been struck off and consolidated, it shall be further smoothed and consolidated by means of a longitudinal float of a suitable design approved by the Engineer. In this operation, the longitudinal float shall be worked with a sawing motion, while held in a floating position parallel to the road centerline and passed gradually from one side of the pavement to the other. Movements ahead along the centerline of the road shall be in succesive advances of not more than one-half the length of the float.

(*d*) *Straightedging*—After the longitudinal floating has been completed and the excess water removed, but while the concrete is still plastic, the slab surface shall be tested for trueness with a 10-ft straightedge swung from handles 3 ft longer than one-half the width of the slab. The straightedge shall be held in successive positions parallel to the road centerline in contact with the surface and the whole area gone over from one side of the slab to the other. Advance along the road shall be in successive stages of not more than one-half length of the straightedge. Any depressions found shall be filled immediately with freshly mixed concrete, struck off, consolidated and refinished. High areas shall be cut down and refinished. The straightedge

testing and refloating shall continue until the entire surface is found to be free from observable departures from the straightedge and the slab has the required grade and crown.

(*e*) *Belting*—After straightedging when most of the water sheen has disappeared and just before the concrete becomes nonplastic, the surface shall be belted with a two-ply canvas belt not less than 8 in. wide and at least 3 ft longer than the width of the slab, or with an approved wooden belt. Hand belts shall have suitable handles to permit controlled uniform manipulation. The belt shall be operated with short strokes transverse to the road centerline and with a rapid advance parallel to the centerline.

(*f*) *Brooming*—After belting and as soon as surplus water has risen to the surface, the pavement shall be given a broom finish with an approved steel or fiber broom, not less than 18 in. wide. The broom shall be pulled gently over the surface of the pavement from edge to edge. Adjacent strokes shall be slightly overlapped. Brooming shall be perpendicular to the centerline of the pavement and so executed that the corrugations thus produced will be uniform in character and width, and not more than $\frac{1}{8}$ in. deep. The broomed surface shall be free from porous spots, irregularities, depressions and small pockets or rough spots such as may be caused by accidentally disturbing particles of coarse aggregate, embodied near the surface. Brooming will not be required for concrete bases.

(*g*) *Edging*—After belting and brooming have been completed, but before the concrete has taken its initial set, the edges of the slab shall be carefully finished with an edger of the radius required by the plans.

(*h*) *Final surface test*—The Contractor will be held responsible for the correct alignment, grade, and contour specified. Any spots higher than $\frac{1}{8}$ in. and not higher than $\frac{1}{4}$ in. for concrete pavements and higher than $\frac{1}{4}$ in. for concrete bases but not higher than $\frac{3}{8}$ in. above the correct surface as shown by the 10-ft straightedge, shall be ground to the required surface by the Contractor at his own expense. Where deviation exceeds the foregoing limits, the pavement slab shall be removed and replaced by the Contractor at his own expense, as directed by the Engineer.

60. Cold weather concreting

(*a*) Except by specific written authorization, concrete placing shall cease when the descending air temperature in the shade and away from artificial heat falls below 40 F. It shall not be resumed until the ascending air temperature in the shade and away from artificial heat rises to 35 F.

(*b*) When concreting is permitted during cold weather the temperature of the mixed concrete shall be not less than 60 F nor more than 100 F at the time of placing in the forms. The aggregates or water or both may be heated. The aggregates may be heated by steam or dry heat prior to being placed in the mixer. The water shall not be hotter than 175 F; aggregates shall not be used which are hotter than 150 F.

(*c*) When concrete is being placed during cold weather and the air temperature may be expected to drop below 35 F, a supply of straw, hay, grass or

other suitable blanketing material shall be provided along the line of the work. At any other time when the air temperature may be expected to reach the freezing point during the day or night the material so provided shall be spread over the concrete to a sufficient depth to prevent freezing of the concrete. Such protection shall be maintained for at least 5 days. If required by the Engineer, concrete less than 24 hours old shall also be covered by approved canvas or similar enclosures and devices capable of maintaining the temperature within the concrete at 50 F or higher. Concrete injured by frost action shall be removed and replaced at the Contractor's expense.

61. Lighting conditions

When the natural light is insufficient for proper work, operations shall cease unless approved artificial lighting is provided.

CURING

62. Preliminary curing period

The concrete shall be covered with two thicknesses of wet burlap weighing not less than 7 oz per sq yd, cotton mats, or other approved material of highly absorptive quality, immediately after final finishing of the pavement surface. The material shall be kept saturated by spraying and shall remain in place for at least 12 hours.

63. Final curing

For completion of the curing the mats used for the preliminary curing period may be left in place and kept saturated for 72 hours, or they may be removed at the end of the preliminary curing period and the concrete surface protected by keeping the surface covered with water (ponding) for 3 days after placing of the concrete; or by a 1-in. layer of thoroughly wet earth, or sand, or a 6-in. layer of thoroughly wet straw, hay or similar material maintained on the surface of the concrete and kept thoroughly wet for 3 days after placing of the concrete. Other methods of final curing may be used if approved by the Engineer. The sides of concrete slabs exposed by the removal of forms shall be protected immediately after the removal of the forms in such a manner as to provide these surfaces with a curing treatment equivalent to that provided by the method prescribed for the surface.

MISCELLANEOUS

64. Pavement thickness

(*a*) The thickness of the pavement shall be determined by measuring the lengths of drilled concrete cores according to the procedure of the current A.S.T.M. Standard Method of Measuring Length of Drilled Concrete Cores (Designation C 174). At such points as the Engineer may select, in each 1000 linear ft of pavement, 2 or more cores shall be taken and measured. The average thickness of each mile of slab, or fractional mile, will be determined from these measurements.

(*b*) Pavement of which the average thickness is within $\frac{1}{8}$ in. of the thickness required by the typical cross section shown on the plans, will be accepted and paid for at the contract price.

(*c*) For pavement, the average thickness of which is less than the thickness shown on the plans by more than ⅛ in. but by less than ½ in., an adjusted unit price shall be used in payment. This price shall bear the same ratio to the contract unit price as the square of the average thickness of the slab bears to the square of the thickness specified on the plans.

(*d*) Payment will not be made for pavement which is found deficient in thickness by ½ in. or more. Such pavement shall be removed and replaced by the Contractor with pavement of the specified thickness at his expense. When the measurement of any core indicates that the slab is deficient in thickness by ½ in. or more, determination shall be made of the thickness of transverse sections of the slab at 25 ft intervals set off along the centerline of the road in each direction from the affected location until a transverse section of the slab is found which is not deficient in thickness by as much as ½ in. The area of pavement for which no payment will be made shall be the product of the width of pavement multiplied by the distance along the centerline of the road between the transverse sections found not deficient in thickness by as much as ½ in. If the Contractor is not satisfied, he may request additional cores and measurements. Such measurement shall be made at intervals of not less than 200 ft. The cost of additional cores and measurements shall be deducted from any sums due the Contractor unless the measurements indicate that the slab within the area in question is of specified thickness.

(*e*) No additional payment over the unit contract price bid will be made for pavement found to be thicker than the specified amount.

65. Protection of finished pavement

(*a*) The Contractor shall erect and maintain suitable barricades and, when required in the special provisions, shall employ watchmen to exclude traffic from the newly constructed pavement until open for use. These barriers shall be so arranged as not to interfere with public traffic on any lane intended to be kept open, and necessary signs and lights shall be maintained by the Contractor clearly indicating any lanes open to the public. Where, as shown on the plans or indicated in the special provisions, it is necessary to provide for traffic across the pavement, the Contractor shall at his expense construct suitable and substantial crossings to bridge over the concrete.

(*b*) Any part of the pavement damaged by traffic or other causes prior to its final acceptance shall be repaired or replaced by and at the expense of the Contractor in a manner satisfactory to the Engineer. The Contractor shall protect the pavement against both public traffic and traffic of his employees and agents.

66. Public use of thoroughfare

(*a*) Normal, unimpeded use of the thoroughfare of which the proposed pavement is to be a unit, is of value to the public. It is, therefore, mutually understood, that for the sections of the thoroughfare identified on the plans as requiring special traffic handling and for the distances stated thereon,

surfaced road lanes as indicated shall be made available by the Contractor for unimpeded public traffic at all times, and maintained in proper condition throughout the construction period. These lanes shall be of the clear widths stated on the plans, and shall be kept entirely free from encroachment by equipment of the Contractor, by workmen or employees of the Contractor or by storage or transportation of materials intended for the work.

(*b*) The scheme and sequence of construction of the several lanes, slabs and sections of pavement, including the sequence of the shifting of public lanes during progress of construction, shall be as given on the plans or as described in the special provisions.

(*c*) Where the edge of any stipulated public traffic lane is contiguous to an edge of the slab or lane being placed, the Contractor shall provide, erect and subsequently remove, a susbtantial temporary guard fence, as shown on the plans along the prescribed dividing line, which shall be maintained there until the slab is opened to traffic. The Contractor's plan of operation shall be such as to obviate any need for encroachment on the public traffic lane or lanes. Where so shown on the plans, special lanes for the Contractor's trucks and similar vehicles shall be provided, separate from and not interfering with the prescribed traffic lanes. Where the clearance between public traffic lanes and the Contractor's operating equipment is restricted, special delivering equipment may be necessary, designed to deliver and depart within the width of the slab actually being placed without encroaching any public lane.

(*d*) Except where a special bid price for "traffic handling" is required in the proposal and in the special provisions, all cost of handling and protecting traffic, of special equipment, of temporary road surfacing and its maintenance, of temporary guard fences and of other things to be provided or to be done under this paragraph, shall be at the expense of the Contractor.

67. Opening to traffic

Traffic will ordinarily be excluded from the newly constructed pavement for 7 days after the concrete is placed and may be excluded for a longer period if cross-bending tests indicate its advisability. Cross-bending test specimens, prepared at regular intervals from the concrete as it comes from the mixer and cured under the same temperature, moisture and climatic conditions as the corresponding slabs of pavement, shall be employed as a means of fixing the time of opening the pavement to traffic. These beams shall be made and tested in accordance with Section 13. When tests of these specimens indicate that the corresponding pavement has attained a modulus of rupture of at least 450 psi the pavement shall be cleaned, the joints filled and trimmed and the pavement opened to traffic. If this strength is not attained within 7 days, the Engineer may open the pavement to traffic at his discretion. The joint or line of separation between adjacent strips or slabs of concrete, when the pavement is constructed in strips or slabs shall be cleaned and filled with an approved sealing material.

A method of measuring entrained air in hardened concrete that can be used in studying the performance of old concrete structures as well as laboratory specimens of test concrete.

Linear Traverse Technique for Measurement of Air in Hardened Concrete*

By L. S. BROWN† and C. U. PIERSON‡

SYNOPSIS

The method described for the determination of air in hardened concrete permits the examination of 6 x 8-in. and 6 x 10-in. random plane face-ground hardened concrete specimens which more truly represent the aggregate and air voids in the actual concrete than smaller specimens. The construction and use of the instruments are discussed and results of tests are given. Because of the time and equipment necessary to measure air content by means of the integrator, it is not adaptable to field use. However, as a laboratory tool it provides a means for quick and accurate determination of total air.

INTRODUCTION

Although several acceptable methods are in use for measuring the air content of fresh concrete, less progress has been made in developing satisfactory methods for determining the air content of hardened concrete. Verbeck[1] has reported a visual method for determining the amount of air by planimeter integration of camera lucida tracings of polished sections. Rexford[2] has described a method using thin sections of concrete in which the measurements are summations by a Wentworth integrating stage. These methods measure the percent air in the cement paste and convert that figure to one representing the percent air in the concrete. Vellines and Ason[3] have developed a bulk method for determining air content by differential measurement of dry and saturated volumes.

Rosiwal[4] showed that the volume percent of the constituents of a solid could be obtained from measurements along a random line through the solid. Lengths of segments or chords intercepted are summed separately for each constituent. The proportion for any one constituent then is the summation for that constituent divided by the summation of all constituents. Multi-

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plication by 100 expresses the proportion in percent, and the result holds for linear, areal, or volume relations. Percent of constituent A, for example, is given by

$$\text{Percent } A = \frac{A \times 100}{A + B + C + \ldots}$$

In practical application the random line is obtained by first cutting a random plane through the solid, then traversing the surface along a series of straight lines, preferably parallel and uniformly spaced. Intercepts of constituents are measured along these traverses, and the procedure has become known as the linear traverse method. The initial purpose or application of the method was to determine the mineral composition of natural rocks, as revealed in thin sections by the microscope. Wentworth[5] developed an accessory stage whereby separate micrometers accumulated intercepts for assigned minerals, record of unit measurements being unnecessary.

Rexford applied the method to measurement of hardened concretes for air content, using thin sections. With the same microscope equipment, the method can be, and has been, used with polished sections, observed by reflected light. Size of the specimens that can be handled by conventional microscope and Wentworth stage is limited to about 1-in. maximum on a side. Since such small specimens only by chance could afford true representation of aggregate, it has been necessary to measure the cement paste separately. The proportion of air thus is determined on a paste basis, then computed to a concrete basis by means of the paste factor, when known, or an approximation.

While some satisfactory results have been achieved, disadvantages or uncertainties in application of the method with conventional equipment have been noted. Without discussing these in detail, it became apparent that the difficulties could be largely avoided by use of much larger specimen surfaces, surfaces large enough to afford true representation of aggregate and also of the occasional larger air voids that occur in practically all concretes. On such surfaces it would be necessary to measure only air and everything else, at the end obtaining a direct percentage for the air regardless of paste-aggregate proportions.

Two other features of the problem showed the use of larger surfaces to be feasible. (1) Scanning of the larger surfaces would be intolerably slow and tedious at 100× or 150× magnifications used with conventional equipment. Experience showed that magnifications of 30× to 40× were adequate. It was found also that perception of the air voids was greatly facilitated by use of the binocular (stereoscopic) microscope. In other words, scanning could be rapid, effective and precise. (2) The other problem was preparation of the specimen surface. It was found that true polishing was not only unnecessary but a disadvantage. Finely ground surfaces proved more desirable, and it was found that suitable surfaces could be obtained easily and quickly by use of a powered grinder, such as is used in producing terrazzo finishes on concrete.

Accordingly, a mechanical integrator of special design was constructed. In principle it is a large Wentworth stage with only two recording motions. Of the two instruments constructed, one will handle a slab 6 x 8 in., the other 6 x 10 in., the latter figure in each case being the maximum length of a single traverse. These instruments have been used in conjunction with binocular microscopes, generally working at 30× magnification. The purpose of the present paper is to describe the construction and use of these instruments, and the results that have been achieved.

APPARATUS

Integrator

The integrator contains three principal parts: the base plate, main carriage and top plate. The concrete specimen is mounted on the top plate as shown in Fig. 1. As the main carriage and specimen move laterally under the microscope, a differential movement of the top plate is a measure of the air voids while the movement of the main carriage is a measure of the solid components of the concrete. The base plate is 25 in. long and 5 in. wide. The 10-in. main carriage moves along a leadscrew attached to the base plate, the total possible translation being 10 in. Power is supplied either manually by a knurled wheel or by an electric motor at the left end of the screw. The amount of translation is recorded by the lower revolution counter at the right end of the screw. One revolution produces a tenth of an inch of translation. The top 6 x 10-in. plate moves independently along the top of the main carriage. It is operated by the upper handwheel, and its movement is recorded in hundredths of an inch by the upper counter. Traverses may be run in either direction. The ratchet counter at the extreme right in Fig. 1 is used to tally the number of air voids encountered in a traverse, for use in

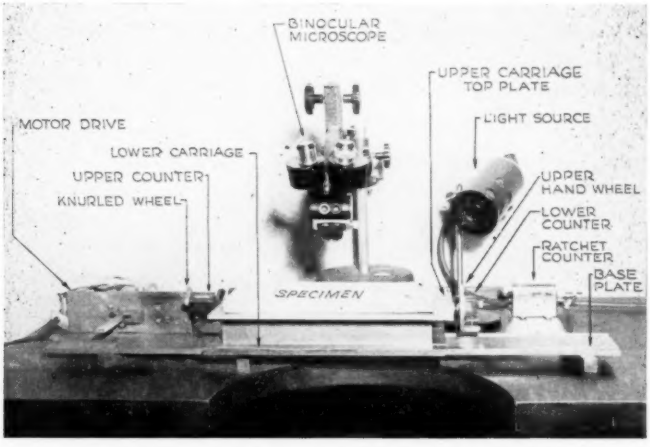

Fig. 1—Apparatus used in the linear traverse method

calculating the distances between voids. This counter is normally placed on the floor where it is operated by the foot.

Microscope

It has been found that a magnification of 30 to 40 diameters is sufficient to reveal the smaller voids. Since stereoscopic vision facilitates the recognition of air voids, a binocular microscope has been adopted. Fig. 1 shows the pillar support, with the extension arm and microscope over the integrator assembly. 2× objective lenses are used with 15× or 20× eyepieces. Crosshairs intersecting at about 30 degrees mounted in one eyepiece are oriented so that the obtuse angles lie to the left and right of the intersection. This gives the operator an unobstructed view of the concrete as it moves laterally across the field toward the intersection, which is used as the reference point. A microscope lamp is positioned to throw a beam across the field at a low angle so that the shadows facilitate recognition of the voids.

Surface preparation

Slabs about ¾ in. thick are cut from the concrete specimen by means of a diamond saw. The blade used in this work is 20 in. in diameter, giving sufficient radius so that cuts are made at one pass through a full thickness of 6 in. Some finish grinding is required which may be minimized by slow cutting. Surface finishing is by honing wheels operated wet by a flexible shaft machine. The coarse wheel is 80-grit and finish wheel is 180-grit. Air voids are sharply defined on the fine surfaces thus produced.

RESULTS

The results of integrations upon two series of concretes are tabulated in Table 1. Series 1 comprised 6 x 12-in. cylinders cast on the job from concrete mixed for a field structure. They were selected to represent a range of air contents. Air content by the pressure method was determined upon each batch from which the specimens were taken. Series 2 comprised concretes prepared in the laboratory using Elgin sand and coarse aggregates of different types, with different percentages of neutralized Vinsol resin to give a range of air contents. The air contents of these batches were also determined by the pressure method. To minimize possible variation of air content between the material tested in the pressure apparatus and the hardened concrete test specimen from the same batch, the concrete was allowed to harden in the bowl of the pressure apparatus and was later removed for the tests described below.

TABLE 1—PERCENT AIR—TRAVERSE METHOD VS. PRESSURE METHOD

Specimen No.	Traverse method: Operator A	Traverse method: Operator B	Pressure meter
1-1	3.6	3.2	3.1
1-2	0.9	1.2	1.0
1-3	9.3	9.2	9.2
1-4	4.6	4.2	4.7
1-5	4.1	3.9	4.2
2-1	1.0	0.7	1.1
2-2	2.2	2.3	2.4
2-3	2.2	1.7	1.9
2-4	5.2	5.1	5.2
2-5	2.0	2.1	1.8
2-6	8.1	7.8	8.2
2-7	1.8	2.0	1.8
2-8	4.7	4.7	4.4

Each slab was so divided as to provide traverses of uniform length and a total traverse length of about 100 in. Independent measurements were made by each of two different operators. The percentages

reported are the arithmetic mean of all traverses on the specimen by each operator. For comparison, the air contents as measured by the pressure method are also presented.

REQUIRED TRAVERSE LENGTH

The standard error of the mean was computed from the deviations of the separate traverses for the air content of each specimen in Table 1. Since specimen No. 2-3 exhibited the largest standard error of the mean (0.4 percent), it was considered useful for further study. Additional traverses spaced at about $\frac{1}{8}$ in. were run to a total length of 282 in. with the accompanying statistical analysis. The values in Table 2 were obtained by considering the following items:

1. Every traverse
2. Every second traverse
   a. 1st, 3rd, 5th, etc.
   b. 2nd, 4th, 6th, etc.
3. Every third traverse
   a. 1st, 4th, 7th, etc.
   b. 2nd, 5th, 8th, etc.
   c. 3rd, 6th, 9th, etc.

TABLE 2—EFFECT OF TRAVERSE LENGTH ON PRECISION OF AIR CONTENT DETERMINATIONS

Items	No. of traverses	Average percent air	Standard error of the mean	Total traverse length, in.	Standard error for 1 in. of traverse
1	34	2.2	±0.22	282	3.69
2a	17	2.5	±0.32	141	3.80
2b	17	2.0 2.2	±0.31	141	3.68
3a	12	2.3	±0.49	100	4.90
3b	11	2.0 2.2	±0.27	91	2.58
3c	11	2.4	±0.38	91	3.62
					Ave. 3.71

Each determination then represents a sampling of the entire finished surface of approximately 50 sq in. The data in the last column make it possible to determine the length of traverse necessary to keep the standard error smaller than any specified amount. To obtain a standard error of 0.4 percent air, for instance, the required traverse length is $\left(\frac{3.71}{0.40}\right)^2$ or 86 in. Hence the 100 in. traverse, which has been adopted as the normal procedure, produces standard errors somewhat below that figure.

MEASUREMENT OF BUBBLE SIZE AND SPACING

T. C. Powers[6] gives the following formula for calculating a spacing factor for the air voids:

$$\bar{L} = \frac{3A}{4n}\left[1.4\left(\frac{p}{A}+1\right)^{1/3}-1\right]$$

where $\bar{L}$ = spacing factor
A = air content as measured by the integrator
n = number of voids per inch of linear traverse
p = paste content of the sample (air not included)

Thus by supplementing the determination of air content with a count of the

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TABLE 3—BUBBLE SPACING FACTORS CALCULATED FOR VARIOUS SPECIMENS

Specimen No.	Percent air	No. of traverses	Mean bubble spacing factor, in.	Std. error of the mean, in.	Total traverse length, in.	Std. error for 1 in. of traverse, in.
2-2	2.2	12	0.0074	0.00053	102.81	0.00514
2-8	4.7	13	0.0089	0.00042	114.18	0.00453
2-4	5.2	12	0.0054	0.00035	103.45	0.00359
2-6	8.1	12	0.0054	0.00029	102.26	0.00294

average number of voids intersected per unit length of traverse, the spacing factor can be calculated.

The results obtained with four of the specimens in the second group of Table 1 are given in Table 3.

The bubble spacing factor and the standard error for a fifth specimen (No. 2-7), which contained less than 2 percent air were much higher than those for the four specimens shown. It may be seen from the last column of the table that the standard error decreases with increasing air contents, indicating that air is more uniformly distributed in specimens with higher amounts of air. The length of traverse required to obtain a given degree of accuracy throughout the range shown in the table may be computed by using the largest standard error shown (0.00514 in. for one inch of traverse). For a standard error of 0.0005 in. the required traverse length is $\left(\frac{0.00514}{0.0005}\right)^2$ or 105.7 in.

CONCLUDING REMARKS

Current investigations of air-entraining concrete indicate that size and distribution of the air voids are variables that may be of as great significance in frost resistance as the total entrained air content. The equipment described above provides a tool for measuring both air content and average bubble spacing with any desired degree of accuracy. With a traverse length of 100 in. the air content may be determined with a standard error of 0.4 percent air and the bubble spacing factor with a standard error of about 0.0005 in. Because of the time and equipment necessary to measure air content by means of the integrator it is not adaptable to field use. However, as a laboratory tool it provides a means for quick determination of total air. It also illustrates the factors of individual void size and distribution that can be determined only by visual observation.

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Discussion of a paper by L. S. Brown and C. U. Pierson:

Linear Traverse Technique for Measurement of Air in Hardened Concrete*

By T. F. WILLIS, KATHERINE MATHER and AUTHORS

By T. F. WILLIS†

Messrs. Brown and Pierson have given an excellent description of equipment and procedures for the determination of the air content in concrete by the Rosiwal "linear traverse method." These, together with their adaptation of a readily available power grinder for preparing specimens, provide the concrete technologist with an excellent tool for the study of entrained air. In addition to the total air content, the specific surface may be obtained. With a slight modification of the procedure, it is also possible to make measurements from which the size distribution and the mean radii of the bubbles may be calculated.‡ As pointed out in the paper, T. C. Powers has indicated the possible effect of these bubble system characteristics on the frost-resistance of hardened concrete. Probably these characteristics also affect the "bleeding tendency" and workability of plastic concrete containing entrained air.

As a result of a visit to the Portland Cement Assn. laboratory some three years ago, at which time Dr. Brown demonstrated their equipment and methods, the Research Division of the Missouri State Highway Department adopted their procedure. Description of a few points in which the apparatus and methods differ from those of Brown and Pierson may be of interest as a supplement to their paper.

The integrating stage has the same basic mechanical features as that of Brown and Pierson, differing only in details of construction (Fig. A). The lower carriage motion (both longitudinal and transverse) is obtained through use of a motor-driven quick-change lathe having a 10-in. swing, a 54-in. bed, and hand-driven cross feed. The hand-driven upper carriage was designed by the Research Division and fabricated locally. It is attached to the lower swivel of the compound rest of the lathe. The principal advantages of this apparatus are (1) by use of the quick-change mechanism a wide range in rate of longitudinal travel can be obtained, (2) because of the sturdy construction of the lathe the upper carriage could be made large enough to ac-

*ACI JOURNAL, Oct. 1950, *Proc.* V. 47, p. 117. Disc. 47-7 is a part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 23, No. 4, Dec. 1951, *Proceedings* V. 47.

†Chief of Research Division, Bureau of Materials, Missouri State Highway Department, Jefferson City, Mo.

‡The basic equations are derived in a "Discussion by T. F. Willis of a paper by T. C. Powers, 'The Air Requirement of Frost-Resistant Concrete' ", *Proc.*, Highway Research Board, V. 29, pp. 203-211, 1949. Details of the method of calculation are given in ASTM *Bulletin* No. 177, Oct. 1951, p. 56.

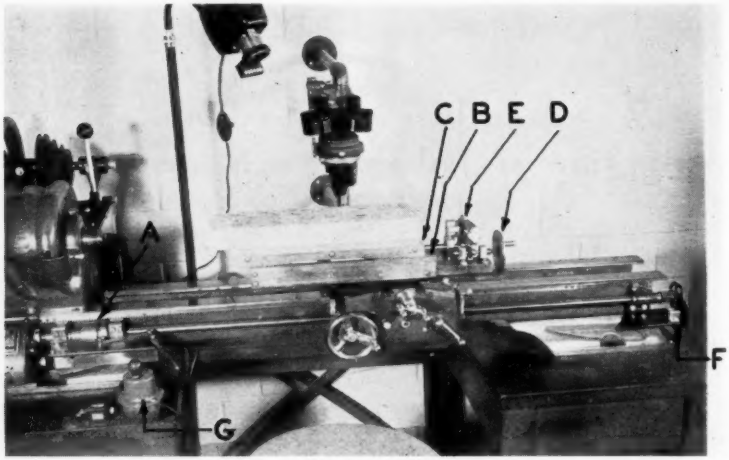

Fig. A—Integrating stage developed by Missouri State Highway Dept. Research Division. A—Friction clutch controlling lathe lead screw (custom made). B—Upper carriage bed fixed on lower swivel of lathe compound rest (custom made). C—Upper carriage (Custom made). D—Upper carriage driving hand-wheel (Custom made). E—Gears driving upper carriage lead screw revolution counter (Boston Gear Co.). F—Lathe lead screw revolution counter (Veeder-Root). G—Lathe motor reversing switch.

commodate specimen sections up to 12 x 22 in., and (3) the lathe, being a mass-produced item, is much cheaper than similar (but smaller) equipment which must be custom-fabricated.

Like Brown and Pierson, we also use a stereoscopic microscope with 35 to 45 magnification for routine analysis of specimens. With our equipment it is possible to recognize and measure sections from bubbles as small as 10 microns in diameter, providing the section was cut near the bubble center. However, it is obvious that many sections of smaller diameter, which result from sectioning bubbles at some distance from the bubble center, should occur. It is not always possible to recognize and measure such sections with the equipment presently used. The error involved has a minor effect on the determination of total air content, but it materially affects the calculated bubble spacing factor.

One other matter concerning preparation of the specimen should be mentioned. To obtain the most sharply defined bubble sections, the face of the specimen exposed by sawing should be moist cured for 3 to 5 days then air dried for a like period before the grinding operation is started. It is thought that carbonation of the surface makes the edges of the bubble sections stronger and less apt to crumble during grinding.

By KATHARINE MATHER*

Dr. Brown and Mr. Pierson are to be congratulated on a most useful con-

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tribution to the technique of micrometric determination of air content. Their results and statistical calculations indicate that the large integrating stage they describe will yield accurate results when used with concrete which can be adequately represented by a 6 x 12-in. cylinder. It is particularly gratifying that the precision of the test results is expressed in standard statistical terms.

It is hoped that the authors will supplement their paper with additional information on (a) the maximum size of aggregate in the concrete tested (It is assumed by the writer to be 1 or 1½-in., since 6 x 12-in. cylinders were the samples used in part of the work) and (b) the traverse spacing which they regard as proper for the type of concrete with which they were concerned.

The writer has continued the work on the use of microscope methods for determining the air content of hardened concrete that was started by Mr. Elliot P. Rexford more than 10 years ago. The methods used by Mr. Rexford were described in his discussion[1] of the paper by Mr. Verbeck.[2] A modified version of Rexford's "Method D" was included in the 1949 edition of the *Handbook for Concrete and Cement*.[3]

Our experience confirms the author's statement that a polished surface is a disadvantage; that the most convenient and comfortable arrangements involve a plane ground but not polished surface, oblique illumination, and a binocular microscope. It may be useful to note that while the specimen handled on a standard Wentworth integrating stage[1,3] will be limited to about 1 x 1 in. if the clips are left on the stage, they can easily be removed. If they are, the top surface of the stage provides a plane surface about 1⅝ x 3 in., which permits the use of a specimen up to about 3 x 3 in. The specimen may be attached to the top plate with plasticine, and moved around so that the whole surface may be traversed.

The studies of air in hardened concrete with which the writer has recently been concerned have almost all involved hardened mass concrete represented by cores 8 or 10 in. in diameter and containing aggregate graded up to 6 in. in size. The saws, grinding equipment, and stage necessary to produce and examine longitudinal slices of such cores in lengths which could be expected to give a representative sample, and the man hours which would be spent in producing and examining such specimens, have made us reluctant to adopt the method described by the authors until other possibilities were proved unsuitable. We have therefore been investigating the possibility of neglecting the coarse aggregate and determining the air content of mortar by the use of a fairly large number of mortar specimens cut from each core.

To reduce the time necessary for each determination we have been experimenting with a point-counter of the type described by Felix Chayes.[4] Since the approach is slightly different from that of the linear traverse method, since it shows considerable promise, and since the principle can be applied to a specimen and a stage of any size, it seems worthwhile to call it to the attention of others who may be interested in its application to concrete research.

Chayes[4,5] developed and described a simplified version of a stage and counter described by A. A. Glagolev.[6,7] In the linear traverse method, the

lengths of intercept of each constituent are measured on a series of equally spaced traverses, and the lengths for each constituent accumulated; in the point-count method, the equally spaced traverses are broken down into a series of equally spaced points. The constituent found at each point in the grid is identified and its presence is recorded. A tabulating counter with a separate key for each constituent is used; such a counter is illustrated in ASTM *Proceedings*.[8,9]* The accumulated totals show the number of times that each constituent was encountered at a grid intersection. The results can be calculated, like those of the linear traverse method, in terms of percentage of each constituent in the total.

The stage which Chayes described was a standard American Optical Co. mechanical stage for use with a petrographic microscope, with simple modifications. A click-wheel with equally spaced notches is attached to the end of the east-west screw and a spring stop mounted on the frame of the stage. As the knob on the screw is turned, the stage translates until it is stopped with a click at the next notch on the wheel. A similar click-wheel and spring stop are attached to the north-south rack and pinion of the stage to give equally spaced traverses. The operator turns the knob, identifies the constituent under the cross hairs of the microscope at each click point, presses the appropriate key on the tabulating counter, and turns the knob again.

The adjustable jaws on a stage of this model can be opened to receive a glass base-plate about $2\frac{3}{4}$ x $1\frac{1}{2}$ in. A slice of concrete or mortar about twice that size can be attached to the base plate with plasticine, and half the area counted; the specimen can then be turned to permit counting the other half. The click-wheels on a stage modified by the American Optical Co. for use in this laboratory give a point spacing of 0.3 mm on the east-west and 0.5 mm on the north-south motion. The spacing used has been 2 or 3 clicks east-west and 2 clicks north-south, giving a grid 0.6 or 0.9 x 1.0 mm. The stage has an east-west motion of 75 mm and a north-south motion of 25 mm.

Results of preliminary tests indicate that the air content of a specimen determined using the point-counter agrees very closely with that determined using the Wentworth integrating stage. The specimens compared were concrete slices about 4 to 6 sq in. total area taken from cores of mass concrete. The traverses counted with the Wentworth integrating stage were spaced $\frac{1}{8}$ in. apart, with total traverse lengths on mortar of between 20 and 25 in., depending on the amount of coarse aggregate in the slice. The point spacings tried were 0.3 x 0.5 mm, 0.6 x 1.0 mm, and 0.9 x 1.0 mm; the last two gave 1750 to 3700 points on mortar per specimen.

The results of these preliminary tests were so encouraging that another stage is being modified for point-count work. The click-wheels to be used will give point spacings of 1 mm east-west and north-south. The stage has an east-west motion of 75 mm and a north-south motion of 50 mm; it can therefore be used with somewhat larger slices than the present stage.

Chayes' results, comparing linear-traverse analyses made with a Wentworth

*The counter illustrated in these references is the type that has been used by the writer; however for the work described here the maximum number of keys required is four.

stage and point-count analyses, indicated that the methods were comparably precise for thin-sections of fine-grained granites. The preliminary tests which we have made suggest that the methods will prove comparably precise for mortar specimens. If this expectation is fulfilled, the point-counter offers a means for measuring air in hardened concrete with a great saving in time and no loss in precision as compared with a traversing stage. Chayes reports that the operating speed of a point-counter is about four times that of a standard Wentworth stage. We have had less experience with the point-counter, but it appears that a specimen can be analysed on it in about one-third the time that would be necessary using a Wentworth stage. No direct comparison of time required for the point-counter and a power-driven traversing stage such as described by the authors is available.

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AUTHORS' CLOSURE

The authors thank Mrs. Mather and Mr. Willis for their contributions. Dr. Brown has been privileged to see and use the instrument described by Mr. Willis. The Missouri Highway Department is to be congratulated on the superior features of its construction. As to employment of the method, the authors agree with Mr. Willis that such voids as are sectioned near the periphery and proportionally far below center, *i.e.*, resulting in shallow, shell-like depressions, may escape detection, but have found the likelihood to exist significantly only for the smaller sizes of voids. Low angle illumination and careful surface grinding serve to minimize the oversight.

Mr. Willis supplies an interesting observation that a slight aging between cutting and grinding tends to improve the finished surface. This feature we had not noticed, but we attribute it more to a slight hardening incident to

drying out rather than to carbonate alteration. A more effective agent, contributing to smooth, continuous surfaces, is thorough curing.

Mrs. Mather's discussion and questions merit perhaps a little elaboration in reply. Our paper stated that the air content of concrete is measurable "with any desired degree of accuracy." Strictly this applies only to measurements of a sample. The other practical requirement is that the sample shall be representative of the concrete. The integrator described in our paper was developed to fulfill the latter requirement. The development followed the finding in earlier efforts with small samples that air in concrete is suitably discernible at a relatively low magnification, hence permitting rapid movement over long traverses.

For the sample to be representative it must be large enough to afford adequate statistical representation of all constituents. How large will that be? Maximum size of coarse aggregate certainly is a prominent factor, since the air occurs only in the cement paste. In the work reported this was 1½-in. What the work has shown is (1) that a 6 x 8-in. surface may be considered a representative sample of a normal concrete with 1½-in. maximum aggregate and (2) that 100 in. of traverse covering this surface determines the air content of the sample within a standard error of 0.4 percent. For coverage of the surface by 100 in., uniform spacing of traverses comes out about ½ or ¾ in., the spacing used in the work reported.

Perhaps it should be pointed out further that distribution of a constituent also exercises an influence more subtle than simple maximum size. Nearly all concretes show an occasional large air void, and the values introduced by the large voids often account for a major proportion of total measured air. There is some indication that a 6 x 8-in. surface is not always adequately representative of the occasional large air void, though it may adequately sample 1½-in. aggregate. To cover this possibility, the routine adopted in our laboratory for measurement of air in 6 x 8-in. cores from concrete pavements is to run 120 to 150 in. of traverse independently on each side of a ¾-in. slab cut axially near the center, and to report the average for the two determinations. The time required, to cut the slab from the core, prepare the two surfaces, and perform the two integrations, is about 6 man-hours.

As to the point-counter technique suggested by Mrs. Mather for measurement of air in concrete, statistically it should be capable of an equal precision with respect to total air. Mr. Pierson has used it successfully in measuring constituents of natural rocks. Possibly it offers a facility greater than the linear traverse method for determination of air in concrete, though it faces the same requirements with respect to adequate sampling and sample preparation. The principal deficiency, in our view, is difficulty in determining average size and space relations of the air voids. This feature is attained in the linear traverse method by addition of a counter on which to tally the number of air voids intersected by a length of traverse.

Mrs. Mather faces a particular problem in her work with concretes contain-

ing up to 6-in. aggregate. Under these conditions there appears to be no immediate escape from work with the mortar fraction and comparatively small specimens. While our experience has shown this approach to yield acceptable approximations, we feel Mrs. Mather will agree that disconcerting variations are likely to appear between specimens. A further element of doubt enters when the mix proportions are unknown. Primarily it was to avoid these uncertainties that we developed the oversize integrating stage, after discovery that the air was suitably revealed at a low magnification.

Consistency of concrete has a predominating influence upon corrosion of reinforcement.

Influence of the Quality of Mortar and Concrete upon Corrosion of Reinforcement*

By RACHEL FRIEDLAND†

SYNOPSIS

In tests to determine the influence of the quality of mortar and concrete upon corrosion of reinforcement the variables studied were cement content, water-cement ratio, consistency, grading and depth of cover. The specimens, stored in moist air or exposed to weather, were tested up to the age of 2 years.

The results indicate that consistency has a pronounced effect upon the protective value of mortar and concrete, and that there appears to exist an "optimum consistency" at which the quantity of rust is practically unaffected by time. It was also found that the usual cement contents in reinforced concrete have only a limited effect upon corrosion. It is concluded that water-cement ratio does not in itself control the rate of corrosion of reinforcement.

INTRODUCTION

It is well-known that spalling of concrete due to corrosion often damages reinforced concrete structures. To cite the "Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete" of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete:[1] "In structures exposed alternately to wetting and drying, this is probably the most common cause of deterioration."

A minimum covering of concrete with a water-cement ratio of about 0.6 is generally required to protect metal reinforcement from corrosion. Where concrete is exposed to sea water an increased depth of protection and a mixing water content amounting to a lower cement ratio is recommended.[2] In Germany,[3] Russia and in Israel[4] a minimum cement content is required for exposed structures. Although there is considerable literature dealing with the corrosion of steel, there appears to be a lack of technical data showing the influence of the quality of concrete upon the rate of corrosion.

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To study this influence small reinforced mortar and concrete prisms were made and the quantity of rust under varying conditions ascertained. It was not intended to measure the amount of rust as it may occur under usual building conditions, but to evaluate a number of factors likely to affect this quantity.

The results of these tests lead to the following conclusions:

1. A dense cement paste which forms an even coating over the reinforcement is the best protection against corrosion. Both attributes, "even" and "dense" are considered equally essential for protection, and any factor influencing these qualities of the cement paste influences *ipso facto* its protective value.

2. Consistency of mortar and concrete has a most pronounced effect upon the rate of rusting, which is not governed by the water-cement ratio, or cement content.

3. Mortar mixes containing 400 kg cement per cu m (675 lb per cu yd) and concrete mixes containing 235 kg cement per cu m (396 lb per cu yd), when of plastic consistency and good grading, afford practically complete protection of the reinforcement in a climate similar to that of Israel.

4. Influence of cement content upon rate of rusting should not be overestimated, and the content generally called for by strength requirements appears to be adequate for protection of the reinforcement, provided the concrete is well graded and of plastic consistency. Concretes of dry and of wet consistency provide inadequate protection against corrosion.

5. Although the average quantity of rust on reinforcement embedded in concrete of dry consistency is smaller than that in wet concrete (2.7 as against 5 in the tests), the local decrease of cross-sectional area may be much greater, because of the concentration of rust at breaks in the cement paste covering the reinforcement.

6. Water-cement ratio, known to control principally compressive strength, durability and water tightness of concrete, does not in itself control the rate of corrosion of reinforcement.

7. Preliminary results show that coarser grading of concrete and mortar tends to improve their protective value. Further study of this phenomenon is required.

8. Increasing the depth of covering enhances the protective value of mortars which in themselves do not sufficiently protect the reinforcement. No effect of depth of covering was observed in mortars which, even when very thin, afforded adequate protection of the reinforcement.

The specimens, reinforced by one or two mild steel bars, were cured and stored for periods from 14 days to 2 years in moist air. Parallel specimens, after 7 days conventional curing, were stored on the roof of the laboratory. The steel was then removed from broken specimens and the amount of rust measured.

The tests were confined to concrete made of aggregates common in Israel (broken dolomitic limestone, a coarse sand called zif-zif and a fine sea-sand, and the only brand of cement produced locally at the time of testing.)

The following variables were studied in tests of 700 specimens:

1. Cement content — Mixes of mortar and concrete 1:10 up to 1:2 by weight (185-700 kg cement per cu m or 312-1180 lb per cu yd)
2. Water-cement ratio — Mortar from 0.5 up to 1.8
   Concrete from 0.5 up to 1.0
3. Consistency — Dry, plastic, wet, sloppy
4. Aggregate grading — Mortar: Fineness moduli from 1.25 up to 2.5
   Concrete: Fineness moduli from 4.2 up to 5.5
5. Depth of covering — From 1 to 6 cm

MATERIALS

Cement

Cement "S" (selectively ground) produced by the Nesher Portland Co., Israel, was used for all mixes. The cement is made by intimately mixing together suitably burnt portland-cement clinker of particle size not larger than 40 microns with both calcareous and siliceous inert materials suitably graded in the particle-size range of 40-200 microns.[5] The mechanical properties of this cement, complying with Israel Standard Specification No. 27, are given in Table 1.

TABLE 1—PROPERTIES OF CEMENT

Fineness	Residue on B.S. sieve No. 170 (size of aperture 0.089 mm) 9.5 percent
Normal consistency	28 percent
Tensile strength (1:3 by weight)	At the age of 3 days—32 kg per sq cm (454 psi) At the age of 7 days—36 kg per sq cm (511 psi)
Setting time (Vicat)	Initial—45 min. Final —2.5 hours
Soundness test (Le Chatelier apparatus)	1.0 mm

Aggregate

The coarse aggregate was a broken dolomitic limestone, the sand, both coarse and fine, natural. The properties of the aggregates are given in Table 2.

Water

The tap water used for mixing contained about 160-200 mg per liter of chlorine.

Steel

The reinforcement consisted of one or two mild steel bars of the following properties:

Diameter, mm	6.09
Yield point, kg per sq cm	3380 (48,000 psi)
Tensile strength, kg per sq cm	4650 (66,000 psi)
Percent elongation	30
Percent reduction in area	76

TEST PROCEDURE

An unsuccessful attempt was made to ascertain the rate of corrosion by measuring changes in the electrical resistance of the bar resulting from the

TABLE 2—PROPERTIES OF AGGREGATES

Chemical composition, percent

	Broken stone	Coarse sand	Fine sand
$CaCO_3$	63.2	81.0	14.0
$MgCO_3$	33.6	8.0	Traces
SiO_2	2.1	3.5	84.0
$Al_2O_3 + Fe_2O_3$	1.1	7.5	1.0
$NaCl$	Traces	Traces	Traces

Mechanical analysis

Sieve size (B.S. sieves)	Percent retained: Large broken stone	Small broken stone	Coarse sand	Fine sand
¾ in.	0			
⅜ in.	56.3	0		
⅜ in.	94.8	40.5		
No. 7	99.1	94.0	0	
No. 14	100.0	100.0	5.4	
No. 25			65.4	0
No. 52			99.4	2.7
No 100			100.0	83.2
Fineness modulus	6.50	5.34	2.70	0.86
Unit weight, kg per cu m	1220	1260	1500	1400

decrease of its area and from the lesser conductivity of iron oxide. The sensitivity of the apparatus employed was, however, inadequate. Measuring the changes in electromotive force between the tested bar and a platinum wire embedded in the concrete by the Poggendorf compensation method also failed to yield satisfactory data. Moreover, rust stains appeared on the outer surface of the test blocks (Fig. 1). Apparently some of the rust separated from the bar passed into the water and appeared at some distance from the seat of corrosion. Obviously, therefore, the rate of corrosion could not be measured quantitatively by either of the above methods.

Hence, a different way of measuring the amount of rust was chosen. Each bar was cleansed by pickling in a solution containing an inhibitor, rinsed with water, then with a one percent sodium carbonate solution, and after another rinse with water, dried well, weighed to the nearest 0.1 mg and immediately embedded in the specimens. The specimens were carefully broken at ages of 14-720 days, the bars removed, cleansed of rust as before and weighed. The amount of rust was calculated from the difference in weight.

The pickling solution was composed of 10 percent hydrochloric acid and an inhibitor. The degree to which the inhibitor fell short of affording complete protection to the steel was determined as follows: Rusted steel bars were immersed in the pickling solution and weighed every hour. As long as they were covered with rust, their weight decreased considerably at every weighing.

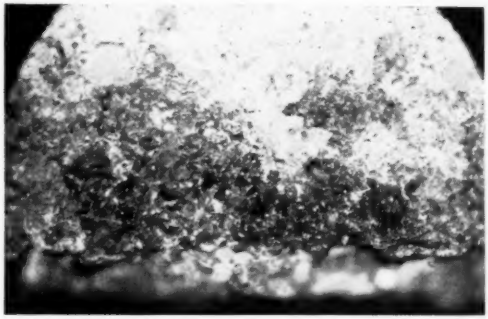

Fig. 1—Rust stains on outer surface of mortar

After some time the differences in the hourly weights became constant and small compared to those at the beginning.

In Fig. 2 these losses in weight are plotted against time for 3 specimens. A considerably larger series of tests was made and the average rate of steel dissolved by the solution in grams per unit area of surface, or "coefficient of inhibitor failure" was determined to be $K = (3 \text{ to } 5) \times 10^{-5}$ grams per sq cm per hour.

Most of the bars removed from the broken specimens and put into the pickling solution lost practically all their rust in one hour. Thereupon the steel started to go into solution. The amount of rust was calculated from the formula

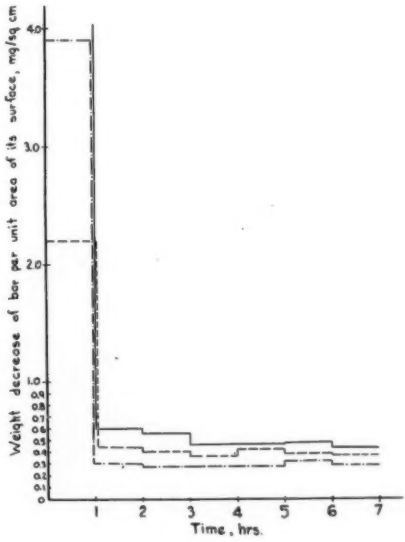

Fig. 2—Hourly losses in weight of steel specimens immersed in the pickling solution

$$R = \frac{W_1 - (W_2 + KAh)}{W_1} \times 100$$

where

R = amount of rust in percent
W_1 = weight of the bar at the time of reinforcing the specimen
W_2 = weight of the bar after removal from the specimen and cleansing
K = coefficient of inhibitor failure
A = surface area of the tested bar
h = time (hours) of immersion of bar in the pickling solution

In the majority of tests KAh was so small in comparison to $W_1 - W_2$ that it could be neglected altogether. Only when the amount of rust was very small did it have to be taken into account.

The removal of the mill scale from the reinforcement may have influenced the amount of rust formed. However, the object of this investigation was not to determine the absolute quantity of rust formed, but to evaluate factors governing the quality of concrete as they affect corrosion under a given set of conditions.

INFLUENCE OF CEMENT CONTENT

Both reinforced mortar and concrete prisms in which the cement-aggregate

TABLE 3—CHARACTERISTICS OF TEST SPECIMENS

Test	Size, cm	Depth of cover, mm	Aggregate	Fineness modulus	Cement-agg. ratio, by wt	W/C
Cement content:						
Mortar	4x4x16	12	35% fine sand 65% coarse sand	2.06	1:10-1:2	
Concrete	7x7x14	30	40% coarse sand 60% small broken stone	4.26	1:10-1:2	
W/C and consistency:						
Mortar	4x4x16	12	35% fine sand 65% coarse sand	2.06	1:6, 1:8, 1:4	0.5-1.4
Concrete	7x7x14	12	35% coarse sand 65% broken stone	4.35	1:6	0.5-1.3
Aggregate grading:						
Mortar	7x7x14	12	Varied amounts of fine and coarse sand	1.25-2.5	1:6	
Concrete	12x12x12	12	Various combinations of large broken stone and coarse sand	3.65-5.54	1:8 (approx.)	
Depth of cover:						
Plastic mortar	12x12x12	10-60	35% fine sand 65% coarse sand		1:6	0.95
Wet mortar					1:6	1.2

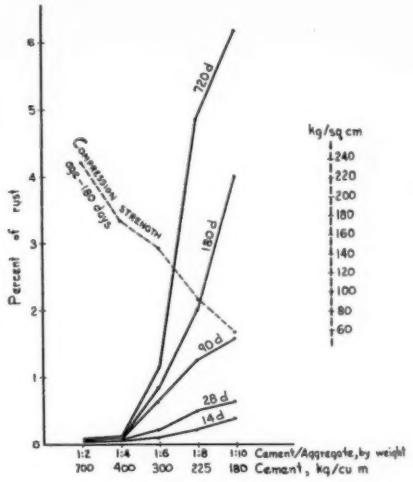

Fig. 3—Relation between cement content of mortar and rate of rusting of reinforcement

ratio was a variable were tested. The characteristics of these prisms are given in Table 3. The reinforcement consisted of a single mild steel bar held in a fixed position while the mortar or concrete was being placed. All the mixtures used were of a plastic consistency with a slump of 4-7 cm. They were carefully mixed by hand, thoroughly compacted and worked around the reinforcement. The specimens were cured and stored in moist air until broken at ages of 14, 28, 90, 180 and 720 days. The bars were removed and the amount of rust determined as described previously. Each point of the curves (Fig. 3-6) represents the average of three like specimens.

Mortar

There was negligible rusting (about 0.05 percent) of reinforcement embedded in rich plastic mortar up to 1:4 mix. (Fig. 3). Mixes 1:2 and 1:4 were almost equally effective as protective coatings.

Below a cement content of 400 kg per cu m (675 lb per cu yd) (1:4 mix) the influence of the amount of cement upon corrosion became increasingly pronounced. Mixes 1:6 or leaner exhibited a greatly accelerated rate of corrosion.

In rich plastic mortar mixes (up to 1:4) negligible rusting progressed only during the first month (Fig. 4). In mixture 1:6 initial rust formation was considerable during the first six months, the curve tending to become asymptotic to time during the second half of the experimental period. Mixes 1:8 and 1:10 corroded severely during the first six months. Although rusting increased to the end of the experimental period, it is safe to assume that, after a longer interval, it will come to a standstill.

Concrete

Plastic concretes containing 235 kg or more cement per cu m (396 lb per cu yd) of concrete (1:8 mix) afford almost complete protection of the reinforce-

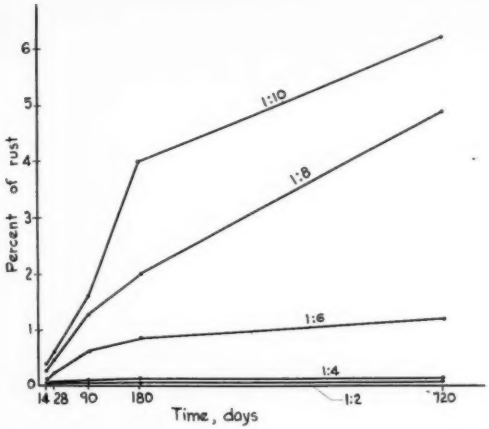

Fig. 4—Time-rust relation in mortars

ment, there being only 0.03-0.06 percent rust at the end of two years (Fig. 5). Increasing cement up to 300 kg per cu m (505 lb per cu yd) improved the protective properties of the concrete. Increases beyond that content showed no further beneficial effect.

With mixes leaner than 1:8 the amount of rust was rather large, being 8.4 times as large in the 1:10 mix as in the 1:8 mix and 8.9 as large as in the 1:6 mix.

Fig. 6 shows that for different cement contents up to the 1:8 mix rusting in-

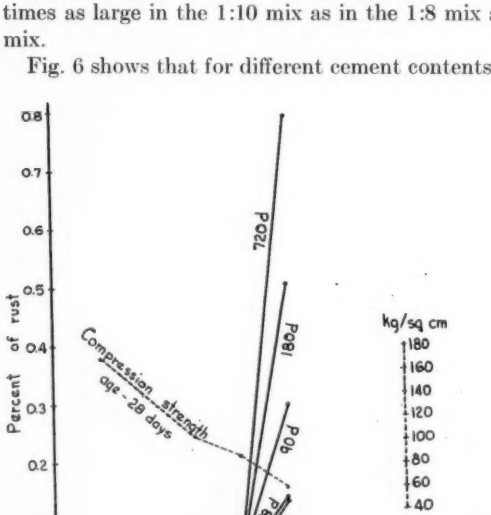

Fig. 5—Relation between cement content of concrete and rate of rusting of reinforcement

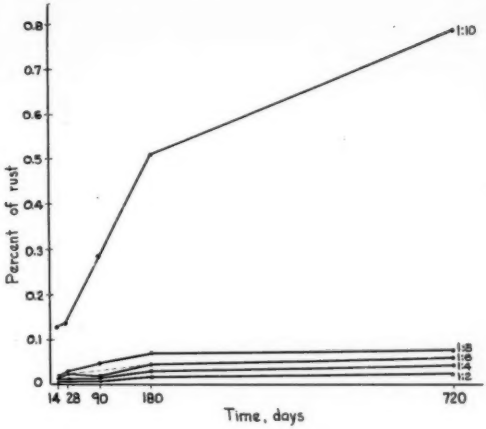

Fig. 6—Time-rust relation in concrete

creased very little, and the curves become asymptotic to the time axis after about one month in 1:2 and 1:4 mixtures and after about three months in 1:6 and 1:8 mixtures. A definite change in the time effect is observed in the 1:10 mix. The curve for this mix indicates active rusting throughout the test period. Specimens for tests have been prepared for further study of this effect up to ten years.

It may be questioned whether results obtained from specimens stored in moist air are applicable to outdoor exposures. If Fig. 9 and 11 are examined it will be seen that, in general, storage in moist air affords a reliable index for outdoor exposure. Hence it may be assumed that from the data given above the 1:8 mix, if of plastic consistency, may be considered the leanest one affording adequate protection to reinforcement in structures exposed to a climate similar to that of Israel. Probably even a leaner mix may be safe in unexposed structures.

It will be seen later that the limitation of this conclusion to concrete of plastic consistency cannot be overstressed.

WATER-CEMENT RATIO AND CONSISTENCY

The characteristics of the specimens used in this series are given in Table 3. The mortar specimens were reinforced with one plain bar while the concrete test pieces contained two bars. About half of the specimens were cured and stored in moist air, the remainder were exposed to weather after 7 days curing in moist air. The specimens were broken at the age of 14, 28, 90, 180 and 720 days and the amount of rust ascertained as described above.

To properly evaluate these curing conditions it should be noted that temperatures in Haifa, Israel, range from 2 to 42 C (36-108 F) with an exceptional 0 C (32 F), but with no freezing. Mean annual rainfall is 600-625 mm (23.6-

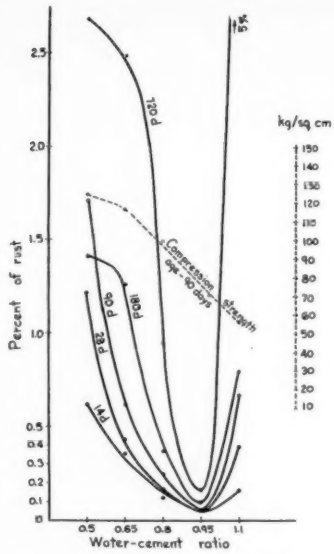

Fig. 7—Relation between water-cement ratio of mortar and rate of rusting of reinforcement

24.6 in.). Usually no rain falls from May until October but humidity may vary from 5 to 95 percent. 1948-49 was exceptionally humid.

Mortar

The data obtained with 1:6 mortar specimens are plotted in Fig. 7. Only the quantity of mixing water was varied between samples, the consistency ranging from dry to wet. All specimens were cured and stored in moist air. Rust was least (0.05-0.17 percent) at 0.95 water-cement ratio, yielding a workable plastic mortar which, however, was deficient in strength (Fig. 7). Moreover, during the two years of testing the amount of rust remained almost constant for this ratio, whereas for mortars with a smaller or larger water-cement ratio the rust-time rate increased considerably, reaching 2.7 percent for the 0.5 water-cement ratio and as much as 5 percent for the 1.1.

To determine whether the curves in Fig. 7 can be regarded as being general, and not dependent on the specific mix proportions, a series of tests on specimens of 1:4, 1:6 and 1:8 mixes was made. The aggregate and the curing conditions were as mentioned before, and the age of testing was 28 days. In Fig. 8 the general trend of the three curves is the same and the results show that minimum rust corresponds to a water-cement ratio of 0.65 for the 1:4 mix, 0.95 for the 1:6 mix and as much as 1.3 in the 1:8 mix. These water-cement ratios all produced plastic mortars. Thus, the fact that consistency has a predominating influence upon corrosion, as indicated by Fig. 7, is confirmed.

Although the object of this investigation was the evaluation of single factors rather than obtaining numerical data concerning corrosion of reinforce-

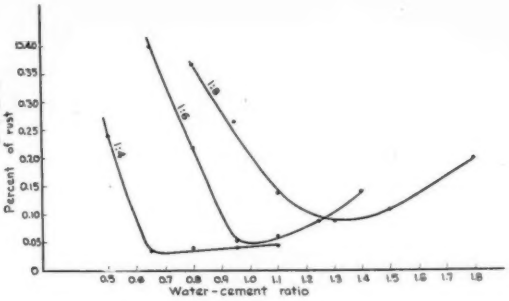

Fig. 8—Relation between water cement ratio of mortars of various mixes and rate of rusting of reinforcement at the age of 28 days

ment as may be met with in exposed structures, it was considered desirable to test also specimens exposed to weather. A series of 1:6 specimens was, therefore, prepared, cured for 7 days in moist air, and then exposed to weather up to two years. Fig. 9 shows clearly that storage in moist air tends to promote corrosion not less than ordinary weather conditions, and that there is a pronounced similarity of the curves obtained. Since, furthermore, storage in moist air is easily controlled, this method of storage was considered more satisfactory for this study.

Concrete

Unfortunately, the coarse aggregate used contained many flat and elongated particles, a common shortcoming of Israeli coarse aggregate. As this has a bearing upon the workability and consistency of the concrete, it might have

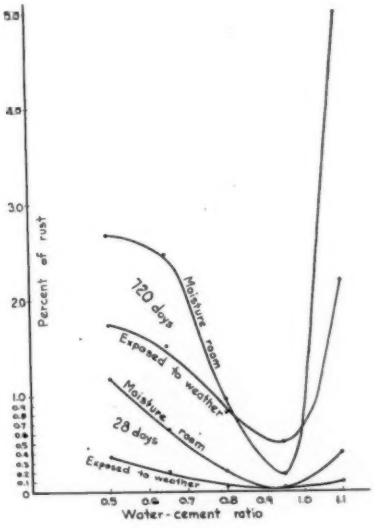

Fig. 9—Comparison between corrosion of reinforcement in mortars stored in moist air and exposed to weather

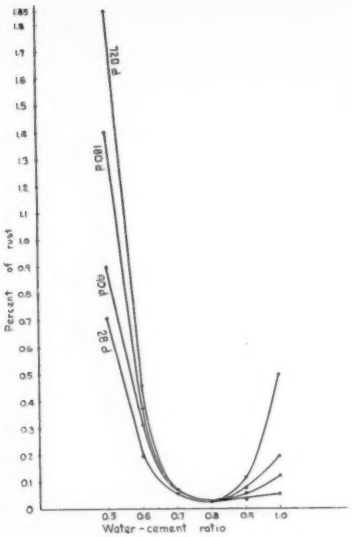

Fig. 10—Relation between water-cement ratio of concrete and rate of rusting of reinforcement

affected somewhat the results obtained, especially because of the pronounced influence of consistency upon the amount of rust. This defect of the aggregate also has considerable influence on the slump of concrete, and it was believed that to define the consistency as "plastic," "wet," etc., gives a clearer idea of the consistency than would the slump measure.

In Fig. 10 results obtained with 1:6 concrete prisms have been plotted against the water-cement ratio which was varied from 0.5 to 1.0 by weight. All but the amount of water being constant, the consistency varied from very dry through wet to very sloppy.

The numerical data differ from those from the mortar specimens but the essential features remain the same. Least rust was found on the bars embedded in plastic concrete. The amount of rust for too dry and too wet mixes was much larger, especially so for the former. In the plastic concrete rust practically did not increase during the two years of testing, whereas the amount of rust of the dry and wet concrete increased considerably. As may be seen from Fig. 11, concrete specimens exposed to weather for 180 days and 720 days confirm the results obtained with mortar (Fig. 9).

Distribution of rust upon the bars

A microscopic examination of the bars removed from the mortar or concrete shows that on bars embedded in dry concrete the rust is concentrated in a few spots on the bar, while for those in plastic and wet concrete it is distributed almost evenly on its surface. Fig. 12 shows the volume of rust formed as viewed through an optical comparator. It was observed in a number of specimens that the corroded surface area was about a quarter or a fifth of the

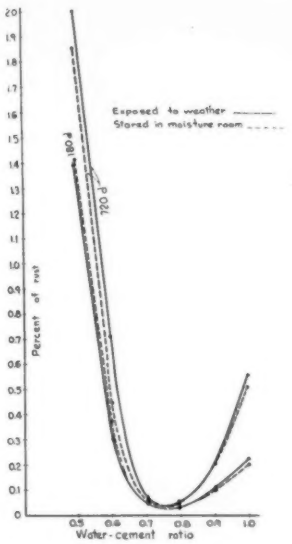

Fig. 11—Comparison between corrosion of reinforcement in concretes stored in moist air and exposed to weather

total, which over two years brings the localized decreases in diameter to about 1 mm out of 6.

AGGREGATE GRADING

The mortar specimens for these tests were reinforced with two bars, the concrete cubes with one bar. The aggregate proportions and other data are given in Table 3. All the mortar mixes were of plastic consistency, while the concrete mixes were of wet consistency. The mortar specimens were cured and stored in moist air.

Mortar

The general trend of the data from tests made at the age of two years indicates that the coarser grading improves the protective value of mortar.

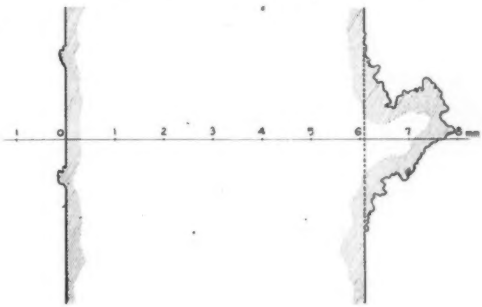

Fig. 12—Profile of rusted steel bar viewed through an optical comparator (× 30)

The spread of the data obtained with mortar of the same grading does not justify more definite conclusions until more numerous tests of specimens with different cement contents are made.

Concrete

Wet consistency was chosen for this series of tests in order to obtain well defined results. The specimens were cured for 7 days in moist air, then stored in open air until tested at an age of 180 days and two years.

The data show that here, too, the coarser grading enhances the protective quality of concrete, but unfortunately the spread of the data was too large to warrant definite numerical conclusions.

Probably one of the reasons why closer agreement between data was not obtained lies in the absence of a method for adequately measuring the consistency of mixes of varying gradings. Hence, in making specimens of equal consistency visual examination had to be depended on, and it is possible that the consistency varied slightly. This, in turn, was likely to make the results somewhat inconsistent, because of the pronounced influence of consistency upon corrosion. Because of the difficulty in controlling the consistencies of mixes with different gradings within close limits, the inference was drawn that only the statistical analysis of a large body of data will support quantitative conclusions.

EFFECT OF DEPTH OF COVERING

Mortar specimens were reinforced by a single mild steel bar with a covering depth varying from 10 to 60 mm. Other data are given in Table 3. Two series of specimens were prepared: one with a water cement ratio of 0.95 yielding a plastic mortar, the other with a water-cement ratio of 1.2, yielding a wet mortar. The specimens were exposed to weather and tested at the age of 2 years.

Plastic mortar

Throughout this series the quantity of rust formed was small (about 0.04 percent) the mixture being of an "optimum" consistency, good grading and adequate cement content. No effect of depth of covering has been observed, the rusting of bars with 10 mm cover being as small as that of bars covered by 60 mm of mortar. This indicates that an even dense coating of cement paste, even when very thin, forms an excellent protection for reinforcement. Such a coating protects to a degree which renders void the role usually allotted to the depth of covering.

Wet mortar

In this series the effect of depth of covering was very pronounced, with an average of about 1 percent of rust for the 10 mm depth and only 0.07 percent for the 50 and 60 mm depth.

Because many specimens were damaged, data were obtained only for depths up to 15 mm and from 50 to 60 mm. Even though insufficient data were

obtained to present a curve it seems safe to assume that with a cement paste which is in itself deficient, additional depth of covering contributes to the protection of reinforcement.

ACKNOWLEDGMENTS

All tests were made at the Building Materials Testing Laboratory of the Hebrew Institute of Technology, Haifa, Israel. Thanks are due to the President of the Institute and to Prof. H. Neumann, Head of the Laboratory, for the facilities in carrying out this work, to Prof. H. Heimann for suggestions with regard to method of testing and for help in choosing the inhibitor, and to Prof. M. Reiner for discussion. Special acknowledgment is due to Research Assistant N. Zalmanoff, for assistance in carrying out the investigation and for many valuable suggestions.

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Discussion of a paper by Rachel Friedland:

Influence of the Quality of Mortar and Concrete upon Corrosion of Reinforcement*

By SERGEY STEUERMAN and AUTHOR

By SERGEY STEUERMAN†

The procedure selected by the author to determine the amount of rust accumulated on the steel surface during a corrosion test required a thorough cleaning of the test bars prior to their embedment in concrete. The laboratory results are exact, clearly presented and will undoubtedly be useful in future studies of reinforcement corrosion. However, the chemical cleaning of the steel surface which removed the last traces of rust from the reinforcing bars has eliminated the possibility of a chemical reaction between the rust and the cement paste, thus creating a condition not found and not desired in field practice.

A reinforcing bar—rusty prior to its embedment—will have a clean, rust-free surface when removed from hardened concrete. Obviously the rust entered into the cement paste of the concrete surrounding the reinforcement, and this process continued until all rust had been removed from the steel surface.‡ Rust and steel powder are used today commercially as a cement admixture to produce a special concrete which expands when cured in the dry, its expansion coefficient materially increasing when cured under water. It must be concluded, therefore, that due to the reaction between the cement paste and the rusty reinforcement surface, a "jacket" of expanding concrete is formed adjacent to this reinforcement. When a reinforced concrete beam is cured in the dry, the "normal" concrete shrinks, whereas the jacket concrete expands; hence the hardening concrete of this jacket is compressed between the shrinking outside concrete and the steel bar. This compression of the jacket concrete is even greater when the beam is cured under water; although the normal concrete has a slight tendency to expand, the difference between the coefficients of expansion of the jacket and that of the normal concrete is greater. Concrete hardening under pressure obtains a higher density and strength, therefore the chemical reaction between the cement paste and a rusty reinforcing bar produces a jacket of special concrete of high density and strength.

*ACI JOURNAL, Oct. 1950, p. 125. Disc. 47-8 is a part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 23, No. 4, Dec. 1951, *Proceedings* V. 47.

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‡It can be surmised that the cement paste enters, if only for a minute depth, into a reaction with the steel itself.

The higher density of the jacket concrete provides an additional protection for the reinforcement, which may bring about results different from those found by the author. Moreover, the presence of the expanding concrete jacket explains the fact of increased bond between steel and concrete in beams cured under water. Finally, the existence of the high strength concrete jacket helps to solve the problem of increased ultimate strength of bars embedded in concrete.

Since the cleaning done by the author did not change the properties of the steel itself, a comparison between the behaviour of the clean and the rusty reinforcement can be obtained, following the author's procedure—by parallel tests with rusty and cleaned steel. For example, ten pieces of equal length cut from the same reinforcing bar can be divided into two groups of five each. One group is to be chemically cleaned and the amount of rust determined and then all ten pieces placed in forms containing concrete from the same batch. Results obtained by submitting both groups to the same corrosion test will show the additional protection provided by the concrete jacket. A microscopic analysis of the jacket concrete may provide valuable information regarding its texture and composition.

The writer realizes the difficulties entailed in the study of the properties of the concrete jacket, but hopes that the author will find it possible to extend the study of reinforcement corrosion to the general problem of the chemical reactions at the reinforcement surface.

AUTHOR'S CLOSURE

The author fully realizes the limitation of her investigation in so far as the removal of the rust from the reinforcement before its embedding may influence the amount of rust formed. But the object of the investigation being the evaluation of the single factors as they affect corrosion, there is a certain advantage in cleaning the steel of rust, as rust changes in quantity from rod to rod and even from section to section of a single rod. It follows that if uncleaned reinforcement were used the measurements of the small quantities of rust formed under different conditions could be misleading.

The theory of a chemical reaction between the cement paste and the steel or the rust has—as far as the author knows—not been proved, and there seems to be little justification in taking it for granted. The well known phenomena mentioned by Mr. Steuerman can be explained by surface action between the reinforcement and the cement paste resembling to some degree the action between glass and bone glue or zinc and *gummi Arabicum*. This does not exclude the effect that a thin layer of rust on the reinforcement may have upon further rusting of the steel or upon the bond.

The author readily agrees that additional study is needed before the results presented in her paper can be directly applied to field practice. This study is already in hand.

Exploration of high air contents and various sand gradings throws new light on the design of mixes for mass concrete. Increase of entrained air from 4½ to 10 percent was found to result in little loss in compressive strength.

Proper Sand Grading Improves Mass Concrete*

By THOMAS B. KENNEDY†

SYNOPSIS

Two series of concrete mixtures were designed using 6-in. traprock coarse aggregate and eight separate gradings of natural sand ranging in fineness modulus from 3.60 to 1.35. Tests were made of the plastic concrete, and specimens were cast for tests of compressive strength, resistance to freezing and thawing, and drying shrinkage. Both series of concrete mixtures had a cement content of 2.5 bags per cu yd; one had a normal air content—4½ ± 1½ percent in the portion of the mixture passing the 1½-in. sieve—and the other had a high air content—10 ± 2 percent in the portion of the mixture passing the 1½-in. sieve. Tests indicate that good durability in freezing and thawing can be obtained within the normal air content range with fineness modulus between 2.50 and 2.90. With increased air content, however, the fineness modulus range can be increased to extend from 1.58 to 3.24. Compressive strength was generally affected adversely by increased air content, but not to a serious degree. Drying shrinkage was less with normal air content mixes than with high air content mixtures. It was least when a fineness modulus of 2.52 was used, little difference being apparent between the high and normal air content mixes with this fineness modulus. The air-entraining admixture requirement increased greatly as the fineness modulus of the sand decreased. The water ratio also tended to increase with decreasing fineness modulus.

INTRODUCTION

When the cement factor of concrete becomes as low as 2½ bags per cu yd, the need for optimum grading of the fine aggregate and its close control becomes important if a reasonable water-cement ratio is to be maintained and a high-quality concrete produced. A great deal of mass concrete construction is being done throughout the country by the Corps of Engineers and the tendency in that organization is toward lower cement factors and lower placing temperatures, aimed at limitation of the heat rise in the mass and elimination of expensive cooling coils to control temperature rise and limit cracking.

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There is evidence that the air content of concrete should increase with decreasing cement factor and possibly the approximately 3 percent that might be the optimum in a 6-bag paving mix would be entirely too low for a mass concrete mix with a 2½-bag per cu yd cement factor.

Tests were conducted to determine, if possible, the effect of variations in fine aggregate grading and the effect of a greatly increased air content over that considered to be normal upon the following properties of concrete containing coarse aggregate graded from the No. 4-sieve size to 6-in. and having a cement content of 2.5 bags per cu yd: bleeding, air-entraining admixture requirements, water-cement ratio, compressive strength, resistance to accelerated freezing and thawing, and drying shrinkage.

MATERIALS

The portland cement used conformed to the requirements for Type II of ASTM Standard Specifications for Portland Cement (C 150-47). Samples taken from the shipment of cement used in this investigation were analyzed in the laboratory. See Table 1.

The fine aggregate selected for the tests was a clean, sound, silica sand from Georgetown, Miss. Physical properties, except grading, of this material are as follows:

Specific gravity bulk saturated surface dry = 2.62
Organic color = 1
Compressive strength ratio, percent: 3 days = 101, 7 days = 104
Absorption = 0.5 percent
Magnesium sulfate loss, 5 cycles = 3.0 percent
Thermal coefficient of expansion, mortar = 7.0×10^{-6}

The coarse aggregate was a diabasic traprock from Plainville, Conn. The sizes from No. 4 through ¾ in. were recrushed and had excellent particle shape, being roughly cubical. The sizes between ¾ in. and 3 in. were not

TABLE 1—CHEMICAL AND PHYSICAL DATA ON CEMENT USED

Constituent	Percent	Constituent	Percent
SiO_2	22.76	Na_2O	0.14
Al_2O_3	4.09	K_2O	0.71
Fe_2O_3	4.11	P_2O_5	0.02
CaO	63.39	Mn_2O_3	0.08
MgO	3.16	Loss on ign.	1.03
SO_3	1.65	Insol. residue	0.28

Calculated compounds, percent

C_3S	46.96
C_2S	29.91
C_3A	3.87
C_4AF	12.49
$CaSO_4$	2.81

Wagner sp. surface = 1700 sq cm per g
Time of set: Initial — 3 hours, 5 min.; Final — 7 hours, 0 min.
Autoclave expansion = 0.08 percent
Air content = 7.1 percent
Normal consistency = 26.0 percent
Compressive strength, psi: 3 days — 1750, 7 days — 2465, 28 days — 3800

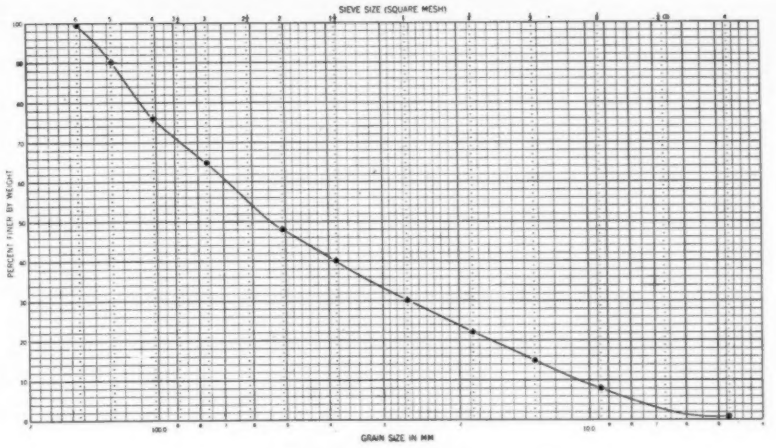

Fig. 1—Sieve analysis of coarse aggregate

recrushed and their shape tended to be somewhat flat and slabby. The sizes larger than 3 in. were not a crusher product, but were hand-picked from the quarry floor; these particles tended to be cubical in shape also. The physical properties of the coarse aggregate with the grading used in all the mixes (Fig. 1) are listed in Table 2.

TESTS

Sand gradings selected were intended to conform to smooth curves wherein decreasing fineness modulus would be accompanied by increasing amounts of material passing the 50 and 100 mesh sieves and the range in fineness modulus selected was intended to cover and extend beyond the normally expected range for concrete work. Gradings 3 and 7, however, did not con-

TABLE 2—PHYSICAL PROPERTIES AND GRADING OF COARSE AGGREGATE

Sieve	Grading used in concrete		
	Individual percent retained	Cumulative percent retained	Passing
6 in.	0	0	100
5 in.	10	10	90
4 in.	14	24	76
3 in.	11	35	65
2 in.	17	52	48
1½ in.	8	60	40
1 in.	10	70	30
¾ in.	8	78	22
½ in.	7	85	15
⅜ in.	7	92	8
No. 4	8	100	0

Specific gravity bulk saturated surface dry = 2.92 Absorption = 0.8 percent
Los Angeles abrasion loss = 12 percent Magnesium sulfate loss
Thermal coefficient of expansion = 3.9 x 10^{-6} after 5 cycles = 0.7 percent

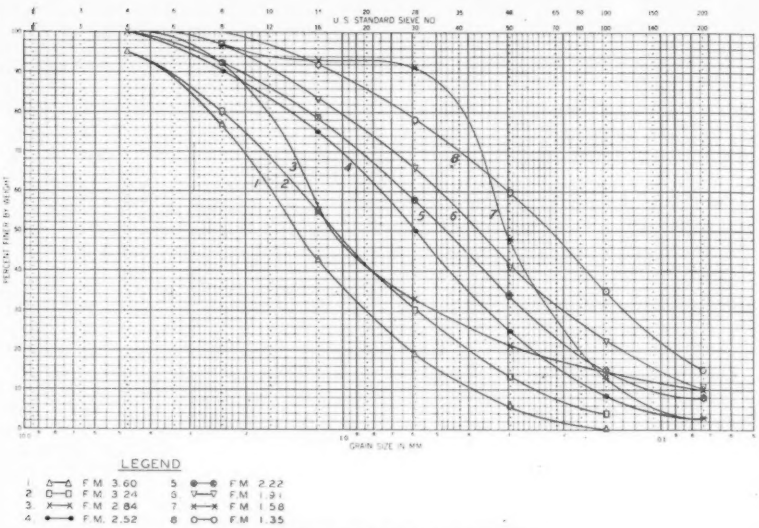

Fig. 2—Sieve analysis of fine aggregate

form to smooth curves and were included in the series because they were gradings that might have been obtained on two construction projects.

A quantity of sand was processed into sieve sizes for recombination later into the gradings desired for the concrete mixtures and test specimens (Fig. 2). The sand was then recombined for the design mixtures and specimen fabrication into the gradations shown in Table 3.

All gradings listed in Table 3 are shown graphically on Fig. 2.

Concrete mixture designs were made using each sand grading in two designs; one with a specified air content of 4½ percent ± 1½ percent in that portion of the mix smaller than the 1½-in. sieve, and the other with a specified air content of 10 percent ± 2 percent in that portion smaller than the 1½-in. sieve. All mixes were designed to have a slump of 2 ± ½ in. and an actual cement factor of 2.5 bags of cement per cu yd of concrete. Insofar

TABLE 3—SAND GRADINGS FOR CONCRETE MIXTURES AND TEST SPECIMENS

Sieve No.	Individual percents retained							
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
4	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
8	18.0	15.0	8.0	10.0	7.0	3.0	4.0	0.0
16	34.0	25.0	37.0	15.0	14.0	14.0	3.0	8.0
30	24.0	25.0	22.0	25.0	21.0	17.0	1.0	14.0
50	13.0	17.0	12.0	25.0	24.0	25.0	44.0	18.0
100	5.5	9.5	6.0	17.0	20.0	19.0	35.0	25.0
200	0.5	3.5	5.0	5.0	6.0	12.0	10.0	20.0
Pan	0.0	0.0	10.0	3.0	8.0	10.0	3.0	15.0
F.M.	3.60	3.24	2.84	2.52	2.22	1.91	1.58	1.35

TABLE 4—MIXTURE DESIGN DATA*

F. M.	S/A, percent†	Air, percent‡	Slump, in.	Bleed, percent§	W/C		Darex, ml per bag	Unit wt., lb per cu ft	Workability
					Wt.	Gpb.			
Low air content (4½ ± 1½ percent‡)									
3.60	27.0	6.1	1**	1.6	0.62	7.0	58	161.4	Fair
3.24	26.0	4.1	2	6.0	0.62	7.0	50	163.8	Good
2.84	25.0	4.7	2¼	10.3	0.62	7.0	50	163.4	Excellent
2.52	24.5	5.5	2½	4.5	0.62	7.0	50	162.6	Excellent
2.22	24.0	5.3	2½	11.0	0.63	7.1	60	162.8	Excellent
1.91	23.0	3.4	2¾	10.0	0.71	8.0	65	163.6	Good
1.58	21.5	4.1	2	13.7	0.71	8.0	40	163.2	Fair
1.35	21.0	6.1	2½	5.4	0.77	8.7	180	160.0	Fair
High air content (10 ± 2 percent‡)									
3.60	24.5	8.5	1½**	1.8	0.60	6.75	120	163.3	Fair
3.24	24.0	8.8	2½	7.6	0.602	6.80	250	159.4	Good
2.84	23.0	9.8	2¾	5.5	0.594	6.70	250	158.7	Excellent
2.52	22.5	10.1	2½	4.2	0.58	6.50	250	158.7	Excellent
2.22	21.5	9.7	2½	6.8	0.58	6.55	400	159.4	Excellent
1.91	20.0	7.5	2¼	13.5	0.58	6.50	450	162.1	Good
1.58	19.5	8.1	2½	4.2	0.65	7.30	400	160.5	Good
1.35	19.0	7.5	2¼	7.2	0.74	8.30	400	159.6	Good

*Cement factor 2.5 bags cu yd.
†Percentage of sand to total aggregate.
‡Calculated on portion of mix smaller than 1½ in.
§Based on the amount of water separating from the concrete during the bleeding test, CRD-C 9-48.
**The mix appeared considerably wetter than this slump would indicate.

as practicable, they were designed to produce the same workability. Bleeding on the fresh concrete was measured for each mixture design. Table 4 presents data on the several mixture designs.

Six 8 x 16-in. cylinders were cast from each mix for testing in compression at 7 and 28 days. Stones larger than approximately 4 in. were removed by hand picking prior to molding the cylinders. Six 3½ x 4½ x 16-in. beams were also cast from each mix; three were for testing in accelerated freezing and thawing, and three with inserts in each end for measurement of drying shrinkage. Coarse aggregate larger than approximately 1 in. was removed by hand picking prior to molding the beams.

One 2-ft (8-cu ft) cube was cast from each mix and after approximately 14-days aging two 10-in. diameter cores were drilled from each block for freezing-and-thawing tests, and for examination of bond condition between coarse aggregate and mortar.

MIXTURE DESIGNS

All mixtures were designed to have the same consistency, the same workability, and a 2 ± ½-in. slump. The concrete was mixed in a 10 cu ft Koehring concentric-zone, closed-drum, rocking tilting mixer. The standard laboratory mixing time was used on all the low air content mixes except that with a fineness modulus of 1.35. This time consisted of 2 min. mixing, 2 min. standing, and 1 min. remixing. The standing period and remixing during the mixing cycle were intended to overcome any tendency of the cement toward flash set. Air contents were determined gravimetrically in

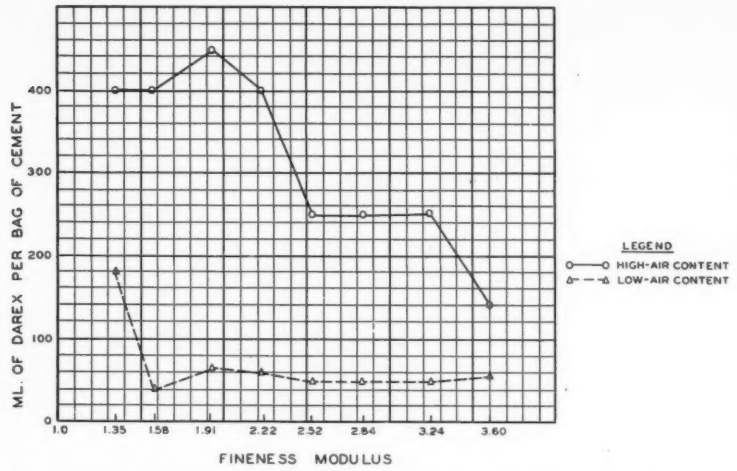

Fig. 3—Effect of sand grading on amount of Darex required to produce a desired air content

a 3½ cu ft measure and were held within the specified range for the low air content mixes except for fineness moduli of 3.60 and 1.35 where the air content exceeded the specified maximum by 0.1 percent. The mixing time of the high air content mixes and the low air content mix having a fineness modulus of 1.35 had to be increased to 6 min. total, with a cycle of 3 min. mix, 2 min. rest, and 3 min. remix. However, it was impossible to achieve the desired high air content even with the extended mixing time, in spite of the fact that a greatly increased amount of Darex was used for the finer gradings. Fig. 3 is a graph of the amount of Darex required to produce both the low and high air content desired plotted against fineness modulus of sand. In making the mixtures it was noted that both the high and low air content mixes made with sand having fineness moduli of 1.35 and 1.58 were somewhat sticky, and did not appear to have as much slump as they actually had when the slump test was made. Mixes containing sands with fineness moduli of 1.91 through 2.84 had excellent workability and were free from stickiness or graininess. This applied to both the high and low air content mixes. Mixes made with sands having fineness moduli of 3.24 and 3.60 were somewhat grainy and appeared to be wetter than the slump test indicated. Workability of the mixes containing the two coarser sands was definitely inferior to the workability of those containing sands with fineness moduli between 1.91 and 2.84. In general, the two coarser-graded sands did not appear to produce mortar that coated the coarse aggregate particles as well as those with finer gradings. From Fig. 4 it will be noted that the water-cement ratio was highest for the finest sand and decreased in the low air content mixes until a fineness modulus of about 2.50 was reached and then

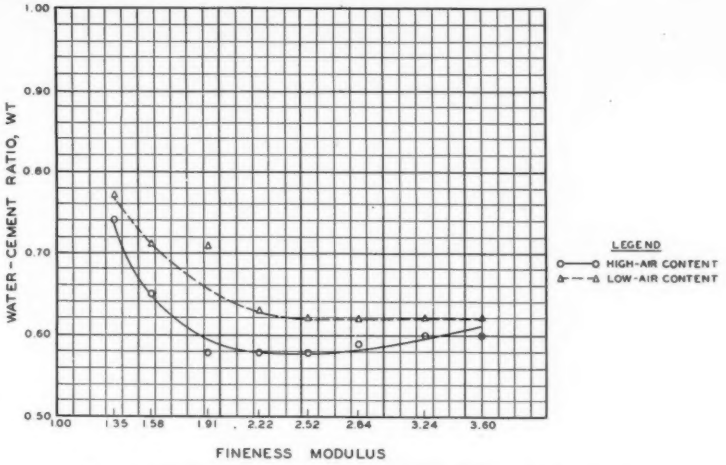

Fig. 4—Effect of sand grading on water-cement ratio of mass concrete

remained constant for the remainder of the series. The high air content mixtures generally required somewhat less water than the low air content mixtures, the finer gradings requiring more water than the coarser gradings. The water-cement ratio curve for the high air content mixtures began to flatten at a fineness modulus of 1.91, but started to rise again at a fineness modulus of 2.84. All the high air content mixtures were more plastic and

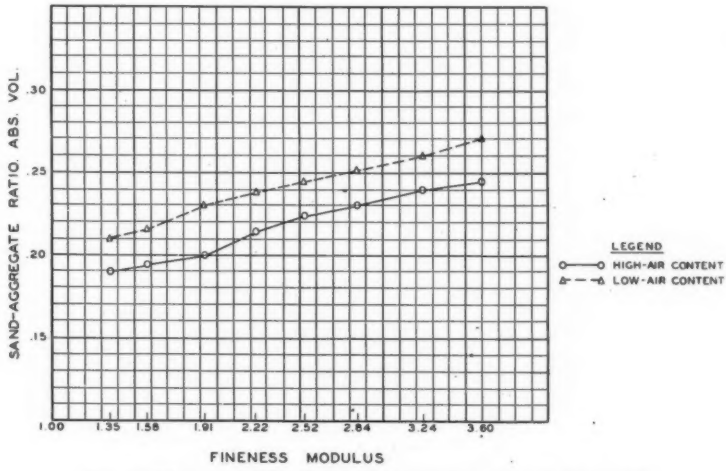

Fig. 5—Effect of sand grading on sand-aggregate ratio, mass concrete

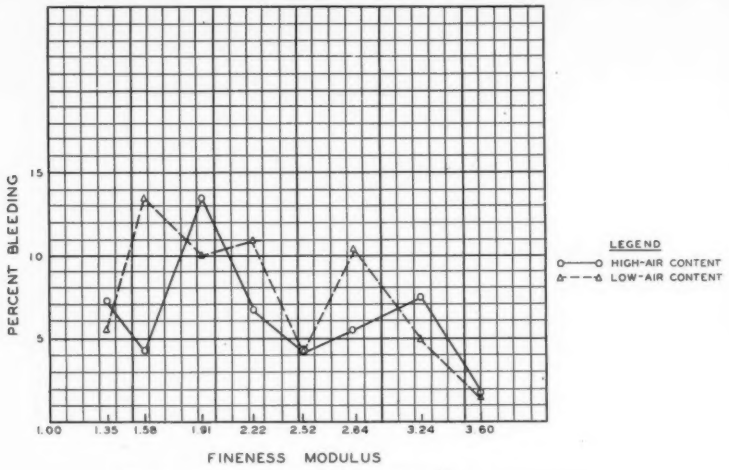

Fig. 6—Effect of sand grading on bleeding of mass concrete

workable than the corresponding low air content mixes. The effect of grading on the sand content of the mixtures is shown in Fig. 5. Sand content increased in both the high and low air content series as the coarseness of the sand increased. Bleeding of the plastic concrete was determined by test method CRD-C 9-48, which measures the amount of water that separates from the concrete in one hour when the sample is subjected to intermittent vibration for 3 sec. out of every 30 sec. Bleeding test results, as shown in Fig. 6, were rather erratic. However, it is not believed that the bleeding tests on the large cobble concrete gave an accurate picture of what actually occurred in the mixes. Rather, where very low bleeding is shown for both the high and low air content mixes with a fineness modulus of 3.60, some internal bleeding must have occurred which did not register in the test.

COMPRESSIVE STRENGTH

The six 8 x 16-in. cylinders made from each concrete mix for compressive testing were consolidated by internal vibration, using a laboratory-size

TABLE 5—COMPRESSIVE STRENGTH OF DESIGN MIXES

F.M.	7-day, psi		Rel. str., percent	28-day, psi		Rel. str., percent
	Low air	High air		Low air	High air	
3.60	1235	1075	87	2025	1745	86
3.24	1320	1115	84	2165	1815	84
2.84	1285	955	74	2025	1620	80
2.52	1530	1295	85	2315	2000	86
2.22	1175	1005	85	2055	2045	99
1.91	1205	1575	131	1920	2225	116
1.58	1020	1335	131	1560	1720	110
1.35	965	605	63	1485	1095	74

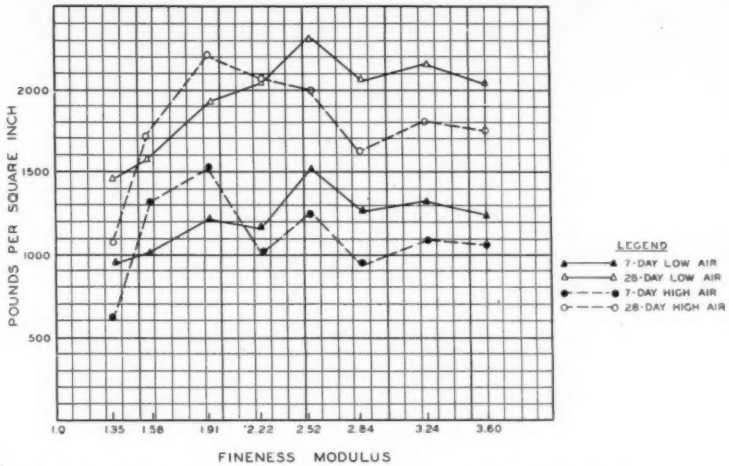

Fig. 7—Effect of sand grading on 7- and 28-day compressive strength of mass concrete

flexible-shaft vibrator. All specimens were cured at 70 F in the fog room until time of test. Table 5 shows average compressive strength values for all the mix designs. Each value shown is an average of three tests.

Fig. 7 shows the relationship between fineness modulus and compressive strength for both the high and low air content mixes. An interesting feature of Fig. 7 is the relatively small difference in compressive strength between the low and the high air content mixes. Another interesting feature is a general tendency for strength to decrease with decreasing fineness modulus. High air contents with fineness moduli of 1.58 and 1.91 produced higher actual strengths than the low air contents.

FREEZING AND THAWING OF SMALL BEAMS

The three 3½ x 4½ x 16-in. beams which were cast from concrete containing sand with each fineness modulus and with both high and low air content, were placed in the accelerated freezing-and-thawing apparatus* after 9 days of fog-room curing. Specimens were tested in an immersed condition and received approximately 12 cycles of test each 24 hours. Temperatures in the concrete ranged between 0 and 42 F. Fig. 8 shows freezing-and-thawing durability factors at 300 cycles of test for each sand grading with both air contents. Good durability was exhibited by all the high air content mixes except those containing sand with fineness moduli of 1.35 and 3.60. Good durability was shown over a much narrower range in the low (normal) air content mixes, with the best durability in the fineness moduli range between 2.50 and 2.90.

*This apparatus is described by Charles E. Wuerpel and Herbert K. Cook in the *Proceedings*, A. S. T. M., V. 45, 1945, pp. 813-823.

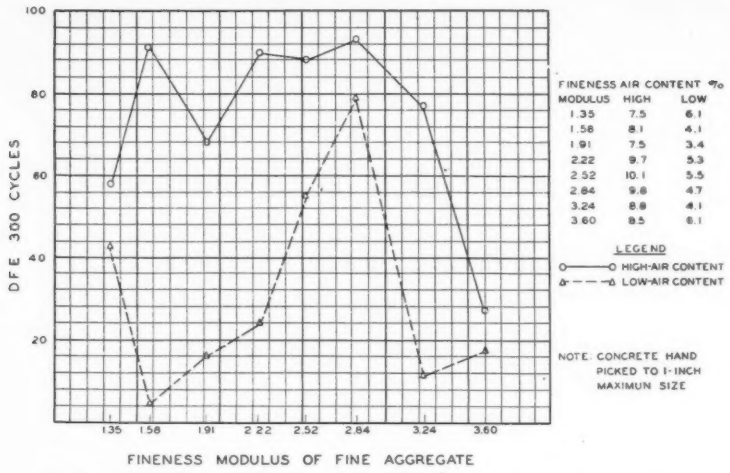

Fig. 8—Effect of sand grading on freezing and thawing durability of mass concrete

DRYING SHRINKAGE

The three 3½ x 4½ x 16-in. beams with measuring studs in each end, cast from concrete containing sand with each fineness modulus and with both high and low air contents, were cured for 9 days in the fog room at 70 F after which they were removed to laboratory air at 70 F where they were measured periodically for length change. No humidity control was maintained. The specimens generally reached maximum shrinkage between 95 and 150 days; values for the maximum shrinkage for each fineness modulus concrete are shown in Table 6. It will be noted that specimens made from concrete with a fineness modulus of 2.52 had the least shrinkage.

After reaching a point of maximum shrinkage each series of beams showed a slight and continuing increase in length with storage in the laboratory air up to the time of this report, which was approximately 300 days.

BOND OF MORTAR TO COARSE AGGREGATE

Macroscopic examination of the core surfaces shows visible hiatus underneath coarse aggregate particles with all sand gradings tested, however, the

TABLE 6—MAXIMUM DRYING SHRINKAGE OF 3½ x 4½ x 16-IN. BEAMS, PERCENT

F.M.	High-air	Days	Low-air	Days
3.60	0.058	125	0.043	95
3.24	0.050	120	0.035	100
2.84	0.062	90	0.036	95
2.52	0.034	95	0.031	95
2.22	0.037	150	0.031	150
1.91	0.071	90	0.037	105
1.58	0.059	150	0.048	135
1.35	0.067	105	0.047	105

high air content mixes apparently achieved the better contact between the underneath side of the coarse aggregate particles and the surrounding mortar.

CONCLUSIONS

From this series of tests it appears that the optimum sand grading for mass concrete with a low cement factor and a normal amount of entrained air and with the materials used was approximately 2.50 since maximum durability in accelerated freezing and thawing, maximum compressive strength and minimum drying shrinkage were exhibited at this fineness modulus. Use of a high air content did not affect the compressive strength excessively, and with the finer gradings of sand a somewhat higher than normal amount of entrained air appears of possible benefit. Use of the finer sand gradings did not eliminate bleeding. The use of higher air contents did appear to benefit the underside bond condition between the coarse aggregate particles and mortar matrix.

ACKNOWLEDGMENT

The investigation reported in this paper was made for the Office, Chief of Engineers, Corps of Engineers, under the general supervision of Herbert K. Cook, Chief of the Concrete Research Division, Waterways Experiment Station, Jackson, Miss. B. W. Steele, Office, Chief of Engineers, was most helpful in furnishing advice and guidance in the planning and execution of the program.

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Data indicates that alkali-bearing phases in cement hydrate readily.

Water-Solubility of Alkalies in Portland Cement*

By J. L. GILLILAND† and T. R. BARTLEY‡

SYNOPSIS

In an effort to show correlation of soluble alkalies with alkali-aggregate reaction, the authors hydrated a number of cements for periods up to 90 days and analyzed water extracts of the ground, hydrated cement. However, the correlation with expansions of mortar bars prepared with reactive aggregate was not improved by considering water-soluble alkalies rather than total alkalies.

The rate at which the alkalies become water-soluble in hydrating cement indicates that the alkali-bearing phases in cement hydrate quite readily.

INTRODUCTION

Since 1940, when T. E. Stanton[1] first described the deleterious reaction between high-alkali cements and certain aggregates, a number of laboratory techniques to measure the extent of the reactivity have been suggested. Because of its directness, the measurement of the expansions of bars fabricated from suspected aggregate and cement combinations, first proposed by Stanton, has been favored by many workers.

Test series, in which a number of cements of varying alkali contents were used with a single reactive aggregate, have been reported by Stanton,[2] Hanna,[3,4] and Blanks and Meissner.[5] Stanton and Hanna found that any relationship between the alkali content of the cement and the expansion of mortar bars, stored in the presence of moisture, exists during the early ages (up to 2 months) only. Even during this period the relationship was not as close as might be desired. Blanks and Meissner, working with concrete as well as with mortar bars, correlated the results to somewhat later ages.

Several investigators have suggested that better correlation might be obtained if the water-soluble alkalies, rather than the total alkalies, were com-

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pared with the expansions. This study, on the rate at which the alkalies in hydrating cements become water-soluble, was made to provide data for such a comparison.

"Water-soluble alkali" in portland cement is a relative quantity, which depends upon the length of time that the cement has hydrated, as well as the testing technique. For cements hydrating at 100 F, substantially all of the alkalies are rendered water-soluble within 90 days, sodium becoming soluble somewhat faster than potassium does.

Inasmuch as the alkalies do become water-soluble quite readily, the correlation with expansion is not improved by considering the water-soluble alkalies rather than the total alkalies.

EXPANSION MEASUREMENTS ON MORTAR BARS

In order to use the mortar-bar test as a means of evaluating the expansive characteristics of different cements, it is necessary to have a stock of aggregate that is uniformly reactive. This has been difficult to do with natural aggregates.

Similarly, in order to evaluate the ability of various siliceous materials to reduce the expansion resulting from alkali-aggregate reaction, a standard aggregate is highly desirable. The siliceous admixture being used at Davis Dam[6,7] near Kingman, Ariz., is being purchased under a specification which requires a determination of the ability of the material to reduce alkali-aggregate expansion. The standard reactive fine aggregate for the mortar bars in this specification test is Pyrex glass, which has been crushed, washed and screened to sand sizes.

Later in this paper, mortar bar expansions of several cements are compared with the total and water-soluble alkalies of these cements. The details of the technique used for measuring the expansions are as follows:

"Lump cullet," Pyrex glass No. 774, is crushed, washed and graded into the five sand sizes from 8-mesh to 100-mesh. Fines passing the 100-mesh screen are discarded. Twenty percent of each size is used as the sand for the mortar bars. The mix consists of 400 g of cement, 200 g of mixing water, and 900 g of the Pyrex sand. The mortar is cast into three 1 x 1 x 10-in. specimens, fitted with stainless steel inserts for measuring the length change. The specimens are cured in the molds in the moist closet for 24 hours, then stripped and placed in special storage containers above a small amount of water. The containers are sealed, then placed in a storage room maintained at 100 ± 3F. After the 24-hour moist cure, and at the test age, the length of the specimen is measured. The container and specimens are cooled to 70 ± 3F before the container is opened and the measurements taken. The expansion is calculated as a percentage of the original length.

PREVIOUS WORK ON WATER-SOLUBLE ALKALIES IN CEMENT

Lea and Desch[8] have given some results obtained by shaking 15 g of cement with 150 ml of water for 48 hours. Their results showed that 20 to 85 percent of the total alkalies become water-soluble in that time.

Anderegg, Peffer, Judy and Huber[9] ground up cement pats which were 24 hours old, and allowed them to stand for 30 minutes in water. For regular

cements, they found that 0.11 to 0.67 percent alkalies were then water-soluble, representing 24 to 100 percent of the total alkalies. For white cements, not over 2 percent of the total alkalies had become water-soluble.

Another type of test was reported by Kalousek, Jumper and Tregoning,[10] who mixed pastes using a water-cement ratio of 0.35, from which the excess liquid was squeezed at 7 minutes and 2 hours. They then determined the amount of dissolved alkalies in this extract, and on the basis that the ratio of clinker to solution remained unchanged up to 2 hours, calculated the percentages of the total alkalies which had become soluble. These authors reported that, at 2 hours, 4 to 34 percent of the Na_2O and 6 to 62 percent of the K_2O had become water-soluble. However, they noted that the combination of water with the clinker during this period would have the effect of increasing the concentrations of the solutes. As their results were not corrected for hydrate water, they suggest that their computations should serve "only as approximations of the true values."

A.S.T.M. test (C 114-47) for water-soluble alkali was made and reported by Lerch and Ford[11] for the PCA long-time study cements. In the A.S.T.M. test, the combined water-soluble alkalies are weighed as the sulfates, then calculated to equivalent Na_2O. Therefore, the percent of total alkalies rendered water-soluble (in about 2 hours) may be calculated from the following:

$$\frac{A}{X + 0.807Y} \times 100 = \text{percent alkalies rendered water-soluble}$$

where A = percent water-soluble alkali according to C 114-47
X = percent total Na_2O
Y = percent total K_2O

Values calculated in this manner are shown in the fifth column of Table 1. The results show that 4 to 68 percent of the total alkalies have become water-soluble.

TABLE 1—ALKALI CONTENT OF PCA LONG-TIME SERIES CEMENTS

PCA cement No.	Total alkalies*		Water-soluble* (A.S.T.M. method)	Percent of total	Total—flame photometer	
	Percent Na_2O	Percent K_2O			Percent Na_2O	Percent K_2O
11	0.21	0.51	0.27	44	0.19	0.55
12	0.28	0.40	0.10	17	0.28	0.41
12T	0.31	0.40	0.09	14	0.27	0.39
13	0.04	0.19	0.02	11	0.01	0.19
14	0.06	1.30	0.54	49	0.02	1.27
15	0.08	0.23	0.01	4	0.04	0.24
16	0.23	0.46	0.28	47	0.22	0.46
16T	0.23	0.44	0.27	46	0.21	0.42
17	0.08	0.43	0.09	21	0.03	0.48
18	0.12	0.13	0.05	23	0.10	0.10
21	0.22	0.40	0.07	13	0.19	0.42
21T	0.21	0.43	0.09	16	0.20	0.40
22	0.24	0.37	0.06	11	0.22	0.38
23	0.59	0.14	0.06	9	0.57	0.15
24	0.06	1.30	0.75	68	0.01	1.25
25	0.21	0.54	0.31	48	0.19	0.58
31	0.23	0.22	0.07	17	0.22	0.24
33	0.21	0.44	0.19	33	0.19	0.45
34	0.28	0.28	0.15	29	0.25	0.29
41	0.06	1.19	0.44	44	0.00	1.17
42	0.16	0.26	0.03	8	0.03	0.29
43	1.00	0.08	0.28	26	1.00	0.08
43A	0.33	0.01	0.04	12	0.34	0.02
51	0.08	0.22	0.04	15	0.03	0.27

*As reported by the PCA laboratory.

Nekrasov and Evko[12] prepared pastes using 3.5 g of water per gram of cement. The pastes were stirred daily. They found that the concentration of alkali in the water extract increased regularly, and that the alkalies were completely soluble in about 1 month.

DETERMINATION OF TOTAL AND WATER-SOLUBLE ALKALIES

All alkali determinations in the present study were made with a Model 52A Perkin-Elmer flame photometer. The total alkalies were determined by the procedure which has been proposed for adoption by A.S.T.M. and the Federal Specifications Board. Briefly, it requires that 1 g of cement shall be dissolved in dilute *HCl*, the solution filtered and made up to volume. The alkalies in this solution are then determined using the flame photometer.

The procedure for hydrating the cements, and for determining the water-soluble alkalies, is as follows:

Ten grams of cement are placed in a small vial (a separate vial is prepared for each test age). The vial is filled with distilled water, and the mixture thoroughly stirred. The vial is then sealed and stored in an oven at 100 F. During the storage period, if the free moisture disappears from the specimen, the vial is reopened, water added and the vial resealed. At the test age, the vial is broken. The hardened specimen is ground in a mortar, then placed in a 250-ml beaker with approximately 100 ml of distilled water. This extraction is continued for 30 minutes with occasional stirring. At the end of that period, the mixture is filtered, the filtrate being caught in a 250-ml volumetric flask. The hydrated cement on the filter paper is thoroughly washed. Ten ml of 1:10 *HCl* is then added to the flask and the solution diluted to the mark. The water-soluble alkalies are then determined using the flame photometer, calibrated against standards of *NaCl* and *KCl*.

DISCUSSION OF TEST RESULTS

Cements from the PCA long-time series were used in this study. The total alkalies in these cements, as determined in our laboratory, using the

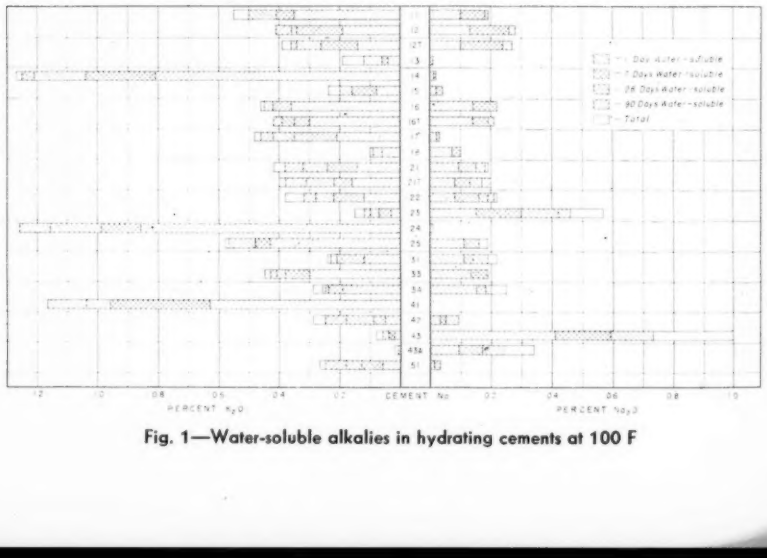

Fig. 1—Water-soluble alkalies in hydrating cements at 100 F

TABLE 2—PERCENTAGE OF THE TOTAL ALKALI WHICH HAS BECOME WATER-SOLUBLE DURING HYDRATION (AT 100 F)

Cement No.	7 days		28 days		90 days	
	Na_2O	K_2O	Na_2O	K_2O	Na_2O	K_2O
11	95	75	100	91	100	91
12	93	83	100	88	100	100
12T	89	67	100	87	100	92
13	*	32	*	63	*	63
14	*	82	*	95	*	98
15	*	67	*	83	*	83
16	91	91	100	98	100	98
16T	90	83	100	93	100	100
17	*	73	*	88	*	96
18	100	90	100	100	100	100
21	78	57	95	76	100	91
21T	65	55	85	78	100	95
22	73	58	86	74	95	84
23	53	47	74	67	81	75
24	*	79	*	92	*	100
25	84	83	100	98	100	100
31	64	88	86	96	100	100
33	100	84	100	91	100	96
34	72	83	80	86	100	90
41	*	83	*	89	*	100
42	*	31	*	62	*	86
43	59	*	73	*	73	*
43A	50	*	68	*	100	*
51	*	48	*	67	*	93
Ave.	78	70	90	85	98	92

*In cases where the cement contained less than 0.1 percent of the oxide, the results were not included in the tabulation or average.

flame photometer, are shown in Columns 6 and 7 of Table 1. The alkali values previously reported by Lerch and Ford[11] are shown in Columns 2 and 3. Inasmuch as these two sets of determinations were not made on split samples, we consider that the agreement is very good.

The amounts of sodium and potassium oxides rendered soluble with time, in cement pastes hydrating at 100 F, are shown in Fig. 1. These values have been corrected for the alkalies contributed by the glass vial, which was determined on a set of pastes made with hydrated lime rather than portland cement. These corrections were found to be quite small. The relative rates at which the sodium oxide and potassium oxide become water-soluble, under these conditions of test, are shown in Table 2. The results indicate that sodium oxide becomes water-soluble somewhat faster than does the potassium oxide. In many of the cements the sodium oxide became completely water-soluble within 28 days, while the potassium oxide required 28 to 90 days. In any case, almost all of the alkalies in a cement do become water-soluble during a few weeks of hydration, indicating that the rate of hydration of the alkali-bearing phases in cements is fairly rapid.

The expansion measurements of the mortar bars made with Pyrex sand and the various cements are shown in Table 3. In Fig. 2, the 28-day expansions from this table are plotted against the total alkali content of the cement, and against the alkalies which have become water-soluble after several hydration ages. It will be noted that the correlation of expansion with total alkalies is as good as it is with water-soluble alkalies at any of the several hydration ages. Evidently, the alkalies become water-soluble so readily

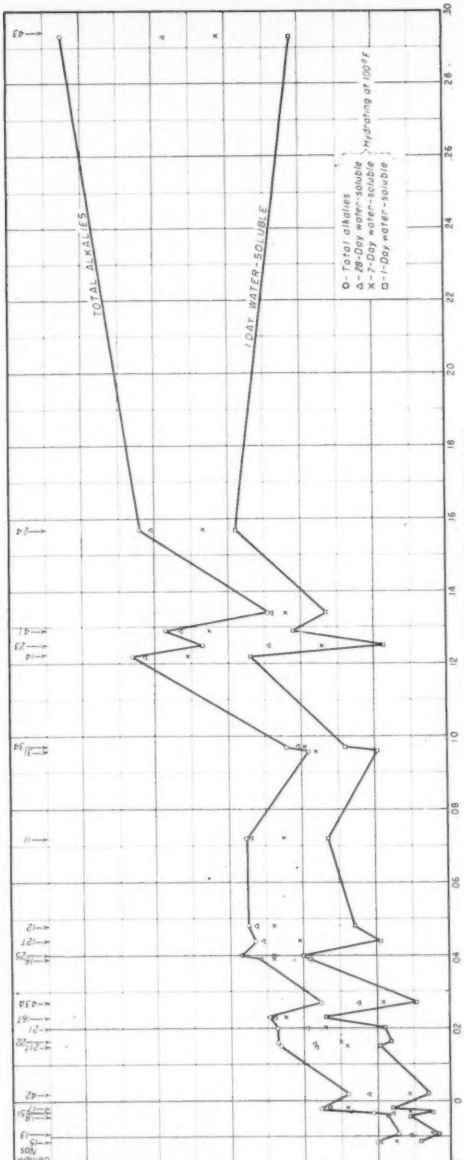

Fig. 9—Relationship between cement alkalies and Pyrex mortar bar expansion

TABLE 3—EXPANSION OF PYREX MORTAR BARS

PCA cement No.	Percent expansion			
	14 days	28 days	2 months	4 months
11	0.040	0.072	0.092	0.094
12	0.028	0.048	0.061	0.062
12T	0.028	0.044	0.061	0.061
13	−0.011	−0.009	−0.006	−0.004
14	0.079	0.122	0.140	0.142
15	−0.013	−0.011	−0.007	−0.002
16	0.017	0.039	0.050	0.056
16T	0.011	0.023	0.036	0.039
17	−0.008	−0.002	0.001	0.003
18	−0.009	−0.004	0.004	0.010
21	0.012	0.020	0.028	0.027
21T	0.006	0.015	0.022	0.024
22	0.006	0.016	0.028	0.031
23	0.060	0.125	0.162	0.167
24	0.113	0.157	0.179	0.183
25	0.034	0.040	0.051	0.051
31	0.042	0.096	0.135	0.153
33	0.095	0.134	0.156	0.166
34	0.053	0.097	0.118	0.133
41	0.107	0.129	0.139	0.147
42	0.000	0.002	0.008	0.018
43	0.182	0.293	0.354	0.392
43A	0.008	0.027	0.055	0.073
51	−0.003	−0.003	−0.001	0.007

during hydration that it makes little difference whether total or water-soluble alkalies are plotted.

In comparing the expansions with the water-soluble alkalies, it is well to bear in mind the limitations on the test imposed by the analytical methods employed. It seems reasonable to assume that only the portion of the alkalies in the aqueous phase of the set cement at any given time will react with the aggregate. However, not all of the alkalies which can be removed by extraction with a large volume of water will necessarily be in the aqueous phase of the set cement. The gels and other hydrous reaction products may adsorb or combine chemically with significant portions of the water-soluble alkalies,[13] which they would release upon dilution. While it would be desirable to attempt a correlation between expansions and the alkalies in the aqueous phase, it is obviously difficult or impossible to isolate the aqueous phase from a set cement.

ACKNOWLEDGMENT

Work on the fabrication and expansion measurements of the Pyrex mortar bars was supervised by O. J. Glantz and L. P. Witte of the Denver laboratories of the Bureau of Reclamation.

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Title No. 47-11

Vacuum-processing equipment is applied to prestressed concrete construction and a design method is outlined.

New Prestressing Method Utilizes Vacuum Process*

By K. P. BILLNER†

SYNOPSIS

The method outlined here was developed to simplify prestressing of concrete to make it generally adaptable to American ways of construction. It eliminates costly anchorages; uses large diameter wires (⅜-in. diameter now available on the market), instead of the customary $\frac{3}{16}$-in. diameter wire, thus greatly reducing the number of wires required; prestresses all the wires in the building element simultaneously and simplifies forming. A simplified method of design calculations for prestressed concrete and the result of tests of a beam so designed are included.

INTRODUCTION

To avoid the manipulation of large numbers of prestressing jacks and the accompanying anchorages, and to reduce the number of wires required, a simplified method of prestressing concrete was developed. By increasing the size of the wires, anchoring them within the member and applying the prestress at the center of the member rather than at the ends, a practical procedure for simultaneous prestressing was evolved.

Anchorage is always important in prestressing because of the high tensile stresses in the reinforcing wires, which generally amount to not less than 100,000 psi. Anchoring by bond to the concrete cannot be depended on if the diameter of the wires exceeds ⅛ in. This problem can be solved simply by anchoring the reinforcement in a manner similar to that of snubbing a rope around a stanchion. The ends of the reinforcing wires are formed into large loops of sufficient diameter to prevent excessive shear exerted by the wires against the concrete core within the loops. All the wires, except the ends forming the loops, are coated with a material such as asphalt, which permits them to slide after the surrounding concrete has hardened (Fig. 1). The uncoated loops develop bond with the concrete in addition to their snubbing effect. The wires are assembled in the form for the concrete element and a thin comb-like partition is inserted at the center. The concrete is cast on both

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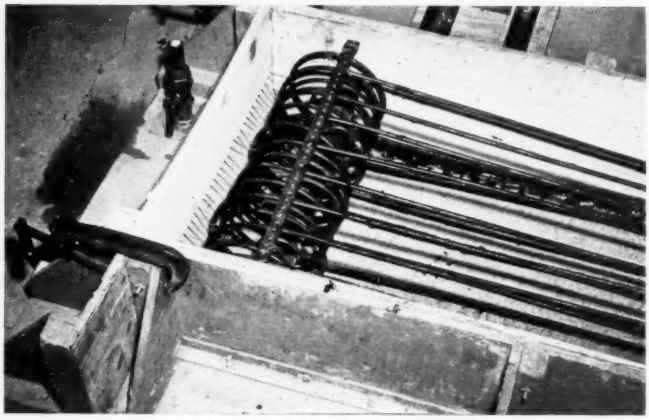


Fig. 1—Looped reinforcement in place in slab form

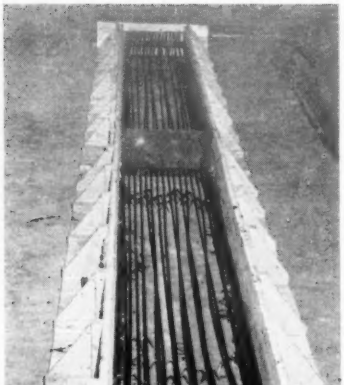


Fig. 2—Partition plate and reinforcement in place in form

sides of this partition, forming two separate units except for the reinforcing wires which run continuously from one end of the specimen to the other, passing through the slots in the partition plate (Fig. 2).

High-strength concrete is a prerequisite. This is achieved by using a mix of low water-cement ratio, which is vibrated and also may be vacuum processed. In this manner it is easy to obtain a strength of 8000 psi in standard 6 x 12-in. cylinders. Test cylinders of the mix used should, of course, be made, and stress-strain measurements on these cylinders, and also on the reinforcing steel used, are essential to ascertain the modulus of elasticity in the concrete and in the steel.

The prestressing is done after the concrete has obtained a strength of not less than 5000 psi which can be had in three to seven days, depending on type of cement used. The wires are stretched by jacking the two units of the beam or slab apart a distance equal to the required elongation t. The cut-off

plate is then loose and is removed. The rectangular opening between the two units is then grouted, using high-early strength 1 : 1 cement-sand mix, with enough calcium chloride to make this mix harden in a few hours. The means for separating the slabs is then released and the prestressed member is complete.

DESIGN CONSIDERATIONS

Elongation in steel

The required elongation for the desired working stresses in steel can be obtained by the formula:

$$t = L\left(\frac{f_s}{E_s} + \frac{f_c}{E_c} + C\right)$$

in which

t is the required elongation
L is the length in inches
f_s, E_s, f_c, E_c, are the customary nomenclature for stresses and moduli of elasticity in the steel and in the concrete.
C is the anticipated coefficient of shrinkage in the concrete.

The measured modulus of elasticity for the concrete should be reduced to approximately half to compensate for expected plastic flow. The coefficient C has been established by the Joint Committee to be from 0.00015 to 0.00045. Tests made by the author indicate that for very thin slabs C may go as high as 0.0006. Generally speaking, the sum of the terms $\frac{f_c}{E_c}$ and C amount to approximately 15 percent of the term $\frac{f_s}{E_s}$.

Basic considerations for a prestressed beam or slab

For the sake of simplicity, the case of a rectangular cross section slab or beam will be considered, but the identical procedure can be applied regardless of the shape of the cross section. This example deals specifically with a 2-ft wide, 12-in. deep element of a bridge slab of 30-ft span, subjected to the heaviest standard H20-S16 loading. In this case no shear reinforcement is required, except at the ends, and there the shear-stresses are taken care of by the looping of the wires. For elements with narrow webs, such as I-beams and box girders, special shear reinforcement must be provided, but in other respects the calculations are the same as for a slab.

In calculation of stresses, the ideal result should be that the concrete, at all times, remains in compression throughout the beam. This means that under dead load the stress distribution in the concrete at the center of the beam should be a triangle in which the apex is in the top surface of the beam and the base of the triangle is at the bottom surface. Under full live load this stress distribution should be reversed so that the apex of the triangle is at the bottom and the base at the top of the beam. The maximum fiber stress at the top and at the bottom should have the same value for the specimen when it is unloaded and when it is under load respectively. A slight

variation in this diagram is permissible because with the high strength concrete used a slight tensile stress in the concrete, not exceeding 200 psi, is permissible. If so, the apex of the respective stress triangles will be slightly inside the concrete surfaces.

Calculations for one-foot width of slab

Notation

Weight of the concrete and steel is assumed to be 150 lb per cu ft
M_1 is the bending moment in inch-pounds for dead load
M_2 is the bending moment in inch-pounds for live load
M is the maximum bending moment for combined dead and live load
a is the steel area per ft width
c is the distance from the center of the steel to the bottom of the slab (Fig. 3)
d is the depth of the slab = 12 in.
f_s is assumed to be 110,000 psi

$$M_1 = \frac{WL^2}{8} \quad (1)$$

Substituting the given values:

$$M_1 = \frac{150 \times 30^2 \times 12}{8} = 200{,}000 \text{ in.-lb} \quad (2)$$

M_2 for H20-S16 load* = $28{,}200 \times 12$ + impact
$= 338{,}000 + 67{,}000 = 405{,}000$ in.-lb (3)

M_2 is therefore in this instance equal to the moment caused by a uniform live load of 300 psf

$$M = M_1 + M_2 = 605{,}000 \text{ in.-lb} \quad (4)$$

$$M_1 = af_s\left(\frac{d}{3} - c\right) = \frac{b \times d \times f_c}{2}\left(\frac{d}{3} - c\right) = 200{,}000 \quad (5)$$

$$M = af_s\left(\frac{2d}{3} - c\right) = \frac{bd \times f_c}{2}\left(\frac{2d}{3} - c\right) = 605{,}000 \quad (6)$$

Substituting the values of f_s and d in Eq. 5, $110{,}000\,a\,(4 - c) = 200{,}000$ (7)

$$c = 4 - \frac{200{,}000}{110{,}000\,a} = 4 - \frac{1.8}{a} \quad (8)$$

*Max. L. L. moment and end shear from 16-ton axle loads (10-ft wide lane and 14 ft between axles). See Standard Specifications for Highway Bridges—The American Association of State Highway Officials, tables pp. 128 and 229.

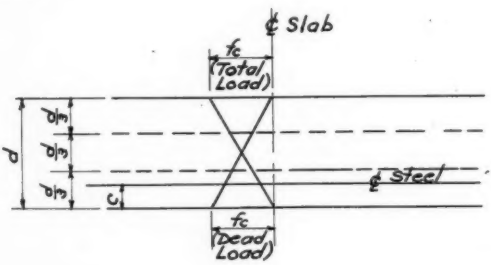


Fig. 3—Load diagram for slab

Substituting for f_s and d in Eq. 6

$$110{,}000\ a\ (8 - c) = 605{,}000 \quad (9)$$

$$c = 8 - \frac{5.5}{a} \quad (10)$$

Combining Eq. 8 and 10:

$$4 - \frac{1.8}{a} = 8 - \frac{5.5}{a} \quad (11)$$

$$a = 0.9 \quad (12)$$

use eight $\frac{3}{8}$-in. round wires

Substituting this value for a in Eq. 8 and 10:

$$c = 4 - \frac{1.8}{a} = 8 - \frac{5.5}{a} = 2 \text{ in.} \quad (13)$$

Solving Eq. 5 in concrete:

$$\frac{bdf_c}{2}\left(\frac{d}{3} - c\right) = 12 \times 6 \times 2f_c = 200{,}000 \quad (14)$$

$f_c = 1400$ psi

Similar solution of Eq. 6 provides a check:

$$\frac{bdf_c}{2}\left(\frac{2d}{3} - c\right) = 12 \times 6 \times 6f_c = 605{,}000 \quad (15)$$

$f_c = 1400$ psi

End reaction:

Horizontal reaction on concrete within the loops at end of beam $= a \times 110{,}000$

$= 0.9 \times 110{,}000 = 100{,}000$

loops = 8.5 diam.

therefore $\frac{100{,}000}{8.5 \times 12} = 1000$ psi

Horizontal shear within loops from each wire = stress in each wire divided by twice the area within the loops $= \frac{110{,}000 \times 0.11}{2 \times 4.25^2 \times \pi} = 107$ psi

Vertical end shear from live load for H20 S16-44—30-ft span including 20 percent impact = 6000 lb

Vertical end shear from dead load $= \frac{150 \times 30}{2} = 2250$ lb

Total end shear = 8250 lb

Vertical shear per sq in. $= \frac{8250}{144} = 57$ psi

The live load for this bridge slab, if uniformly distributed, would amount to 300 psf.

Without changing the thickness or the amount of reinforcement, this slab, if used as a floor in an office building, store or school, could span 42 ft, or if

continued over a center line of columns, it could span 47 ft. The corresponding spans for a garage would be 40 and 45 ft.

These calculations are so simple that any designer, without having to go into deep studies of prestressing, can apply them. Yes, even the boss, who has forgotten this kind of stresses and strains for the more exhausting financial ones, can quickly determine the advantages to be had by prestressing.

Modification in method of calculation

The method outlined above can only be used without modification when the live load is considerably larger than the dead load. If the live load and the dead load are equal, then it will be found that in order to have the same compressive stress in the top of the slab under full live load as the compressive stress in the bottom of the slab without superimposed load, the reinforcing steel will have to be located in the bottom face of the slab.

To still maintain the simplicity of calculation for slabs or beams where there is only a small difference between the live and dead load, it is recommended that the stress distribution in the concrete for dead load be made rectangular, whereas the stress distribution for full dead and live load should be triangular, having the apex of the triangle at the bottom of the slab and the base, which means the maximum fiber stress at the top of the slab. Refinements in this can be made, but it will be found that the possible steel saving is so small that little is gained by deviating from this suggested stress distribution. As an example, take a floor for a garage or a store with a superimposed load of 125 psf. Assume for simplicity that the column spacing, both transversely and longitudinally, is 40 ft. By trial and error method, it will soon be found that a floor thickness of 9 in. is just about right. This is a two-way reinforced flat slab, supported on the columns only. To guard against fire hazards, place the reinforcement so that the center of the steel is 3 in. from the bottom of the slab. This means 2½ in. concrete protection under the bottom face of the steel. It is assumed that one layer of ⅜-in. wire runs longitudinally and another layer of ⅜-in. wire, immediately adjacent to the first layer, runs transversely.

It will be found that the dead load moment M_1 for this two-way reinforced slab will be 138,000 in.-lb.

For both dead and live load M will be 288,000 in.-lb.

The compressive stress in the concrete from dead load only will be found from $f_c{}^1\ (4.5 - 3) \times 9 \times 12 = 138{,}000$

therefore, $f_c{}^1 = 852$ psi

The maximum stress in the concrete for both dead and live load will be found from $f_c = (\frac{2}{3} \times 9 - 3)\ \dfrac{9 \times 12}{2} = 288{,}000$ in.-lb.

therefore $f_c = 1780$ psi

The steel area a_1 for M_1 is derived from $a_1 \times 110{,}000 \times 1.5 = 138{,}000$

therefore $a_1 = 0.836$ sq in.

The steel area for M is derived from $110{,}000\ a \times 3 = 288{,}000$

therefore $a = 0.873$ sq in.

Use eight ⅜-in. round bars in each direction.

The assumed working stress—110,000 psi—in this high-strength steel, bears about the same relation to its yield point—185,000 psi—as the customary working stress in ordinary reinforcing steel, 20,000 psi, does to the yield point for mild steel, 35,000 psi, but there is one cardinal difference in the way the stresses are acting.

In prestressed steel there is only a small variation amounting to not more than 4 percent in the stress of the steel for dead load only and for the combination of dead and live load, whereas in ordinary reinforced concrete the stress from the total dead and live load can amount to several times the stress from dead load only. Long experience has shown that creep in the steel, which could be caused by fatigue in ordinary reinforced concrete, is insignificant, and with the above conditions for prestressed steel it is obvious that the creep is of even less importance.

BEAM TESTS

A 12 in. x 24 in. x 30 ft beam, designed in accordance with the above calculations, was built for test purposes and was loaded to destruction.

The ⅜-in. diameter oil-tempered steel rods used for prestressing had a yield point of 172,000 psi and an ultimate strength of 200,000 psi. These rods were wound into 8-in. diameter loops at each end of the beam. Sixteen rods were used, 8 of which ran horizontally 2 in. from the bottom of the beam. The other 8, also wound into 8-in. diameter loops at each end, were hung in the shape of a catenary. At the center of the beam, these rods were also 2 in. from the bottom of the beam. The bars were coated with asphalt for the entire distance between the two loops, permitting the rods to slip through the hardened concrete with no bond whatsoever. The only part of the rods permitted to bond with the concrete were the two 8-in. diameter loops (Fig. 1 and 2).

At the center of the beam a ¼-in. steel plate was placed. This plate was slotted at the bottom to permit passage of the 16 rods. In effect it separated the beam into two portions 15 ft long. In addition, to expedite prestressing, a transverse opening 4¼ x 10 in. was cast into each portion 6¼ in. on each side of the center line. The blocks used to form these openings were placed directly on top of the steel rods.

A 5 x 2-in. wood block was cast into the lower face of each half of the beam 6 ft 6 in. from each end. The block was centered directly beneath the third rods, approximately 5 in. from the edge of the beam. The purpose of this block was to leave an opening through which the action of the steel rod could be observed and also to permit attachment of an electric strain gage to measure changes in stress in the steel.

The concrete mix was approximately 1 : 1½ : 2½, the coarse aggregate being 50 percent ⅜-in. diameter gravel and 50 percent ¾-in. diameter gravel. The water-cement ratio was 4½ gal. per sack of high-early strength cement. The concrete was very stiff, necessitating vibration in placing. After the beam was completely placed an attempt to vacuum process the concrete was made, but probably had little effect since the concrete was beginning to set.

Five days later this beam was lifted, by means of a lift truck and vacuum lifters, on to 2-in. diameter pipe sections. The blocks used to cast the 4¼ x 10-in. holes were removed from the beam and 3⅞ x 10-in. steel plates were inserted in the holes. Two 240,000-lb jacks were used for the prestressing operation. One jack was placed between the steel plates on each side of the beam (Fig. 4). The jacks were then slowly loaded to 120,000 lb per jack, giving a total load of 240,000 lb. The two halves of the concrete beam moved apart readily under the action of the jacks, and there appeared to be no impediment indicating that the asphalt coated

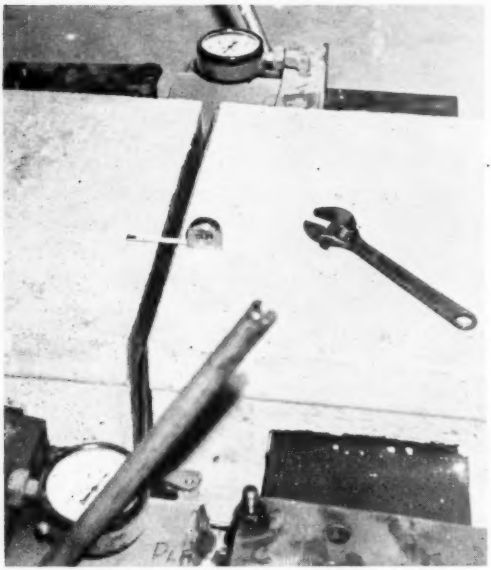


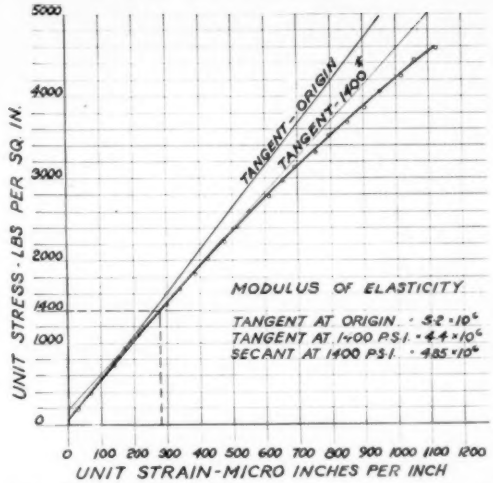
Fig. 4—Slab sections separated by prestressing jacks

rods had not bonded to the concrete. The separation between the two halves of the beam at the 240,000 lb load was 1¾ in. At this point forms were fitted to the sides of the beam, enclosing the space between the two halves, and the space was grouted in with a very rich mix. A vibrator was used during this operation; steel plate restrainers were inserted to replace the jacks and the grout was permitted to set for a day. Then the restrainers were removed. The prestressed concrete beam was now a complete unit ready for loading.

Cylinder test

At the time of casting of the beam three 6 x 12-in. cylinders were cast and vacuum processed. These cylinders, after being cured in the same manner as the beam, that is, by being covered with wax paper and damp sand, were tested at the age of three days. Two of the cylinders had three Baldwin SR-4 strain gages applied to the surface 120° apart. These gages were wired to a Baldwin strain recorder reading to micro-in. per in. and readings of the unit strain were taken at even load increments throughout the duration of the compression test. A deflectometer with an 8-in. gage length, using Ames dials reading to ten-thousandths of an inch, was used on the third cylinder. Again strain readings were taken from the Ames dials. The results of these tests appear as final averages of eight gage readings in Fig. 5. As can be seen from the figure, the modulus of elasticity is a variable figure depending upon interpretation. There are three generally recognized methods of computing the modulus of elasticity for a material such as concrete. The first method, that of computing the modulus by use of the tangent to the curve at the origin yields 5.2×10^6 psi. The second method, that of using the tangent to the curve at the working stress of 1400 psi yields 4.4×10^6, and the third method, that of using the secant to the curve at 1400 psi gives 4.85×10^6.

Since the cylinders were tested at only three days whereas the beam was tested when three weeks old, it is reasonable to assume that the strength of the concrete was higher than the corresponding cylinders and that the modulus of elasticity was undoubtedly higher. Taking this fact into account, it would appear that a value of 5 million psi for the modulus of elasticity of the concrete would be valid. The average ultimate strength of the three specimens was


5000
4000
3000
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1400
1000
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UNIT STRESS - LBS PER SQ. IN.
TANGENT - ORIGIN
TANGENT - 1400
MODULUS OF ELASTICITY
TANGENT AT ORIGIN = 5.2 × 10⁶
TANGENT AT 1400 P.S.I. = 4.4 × 10⁶
SECANT AT 1400 P.S.I. = 4.85 × 10⁶
0 100 200 300 400 500 600 700 800 900 1000 1100 1200
UNIT STRAIN - MICRO INCHES PER INCH

Fig. 5—Modulus of elasticity computed from cylinder compression tests

6500. Therefore, the ultimate strength of the concrete at the test date was probably close to 7000 psi.

Loading of beam

Twenty-three days after casting, the beam was loaded to destruction. Previously this beam had been lifted and set in a frame at each end which supported the beam approximately 9 in. above the floor and permitted loading of the beam by jacking between the concrete beam and a steel beam which was also supported by the frames. Previously, strain gages had been attached on both top and the bottom faces of the beam since the beam was supported far enough above the floor. The gages in corresponding positions on opposite faces of the beam were connected in series, yielding an average value for the two gages. The three gages in each position on the top face of the beam were connected in series and the three gages in each position on the bottom face were connected in series. Thus, at each longitudinal section of the beam at which gages were applied one reading was taken for the top fibers which represented the average of three gages, one reading was taken for the bottom fibers which represented the average of three gages and one reading was taken for each of the three intermediate positions on the faces of beam, which represented the average of two gages. Finally, one gage was attached to one of the steel bars used for prestressing the beam.

The beam was loaded at third points and strain gage readings were taken at increments of 5000 lb total load or 2500 lb on each hydraulic jack.

In computing the averages of readings obtained an interpolated figure was inserted for the load of 13,500 lb since at this total load the live load moment in the middle third of the beam was essentially the same as that for which the beam was designed. These interpolated averages are plotted in Fig. 6 and the proper curves drawn. Curve No. 2, that representing the figures for the strain gages located 2 ft on either side of the center line, is the most important one. Examination will show that four points form essentially a straight line. The fifth point, that of the upper fibers, is considerably off the line of the first four. If a smooth curve were drawn through these five points, the resulting shape would indicate plastic flow in the upper fibers of the beam. This is highly unlikely at the load used. Rather than attempt to draw a

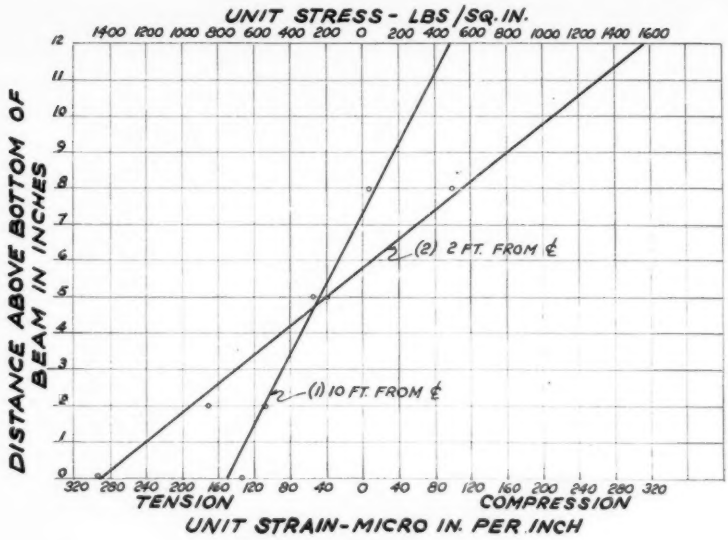


Fig. 6—Stress variation in test beam

smooth curve through the five points, a more valid solution would seem to be to draw a straight line through the first four, since the fifth point, that of the top fiber, represents the average of the 3-gage series, one of which may have been in error, thus throwing off the final result. If a straight line is drawn through the four lower points the resulting change in stress in the lower fiber at the center is 1440 psi against a design assumption of 1400 psi. The resulting stress in the upper fibers is 1560 psi compression as against a design assumption of 1400 psi. The strain gage attached to the steel rod indicated a unit strain of 202 micro-in. per in. at 13,500 lb which is the equivalent of an increase in tensile stress of 6000 psi.

Load deflection

The readings taken every 5000 lb of total load included not only fiber stress readings, but also deflection readings. Readings were taken at the third points and at the center line at both front face and rear face of the beam. The average values are plotted in Fig. 7. The deflection at the 25,000 lb total load was $1\frac{5}{8}$ in. When the total load was removed the beam returned to within $\frac{1}{16}$ in. of its original position. This 25,000 lb total load at the third points represents a live load moment approximately equivalent to twice the design live load moment. Due to failure of one of the jacks it was impossible to continue the loading at the third points beyond 25,000 lb. One of the jacks was transferred to the center line and the loading continued to 25,000 lb. The deflection at the center was $3\frac{7}{8}$ in. When the load was removed, the beam returned to within $\frac{3}{16}$ in. of its original position. It might be added

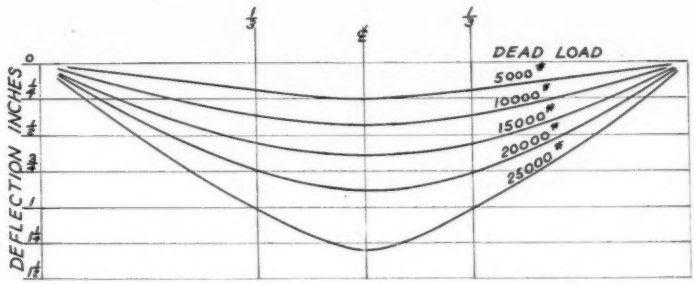


Fig. 7—Deflection curves for third-point loading

that at this extreme load hair line cracks opened under the grout used to fill in the holes in which the steel plates had been placed. Upon removal of the load, these cracks closed up completely and became invisible. The loading was continued to 26,000 lb with a 4⅜-in. center deflection; to 27,000 lb with a 5-in. deflection, and to 28,000 lb with a 5¾-in. deflection. By this time a ⅜-in. wide vertical crack had opened up in the center of the beam. The deflection gradually increased to 7¼ in. at the center line and failure occurred by local buckling of the compressive fibers at the center. When the load was removed after failure, the beam returned to within 1½ in. of its original position. This maximum load of 28,000 lb applied at the center line represents a live load moment equivalent to approximately three times the design live load moment.

PRACTICAL APPLICATIONS

Analyzing the result of the design computations, it will be found that the specimen has nearly three times the carrying capacity of an ordinary reinforced concrete beam of the same cross section. This means that if the live load for design purposes is established, then for the same load, the span can be increased by nearly the square root of three as compared to the maximum length of the same beam if it were not prestressed. In practice, to mention a few examples, this means that spans in a building can be increased from a customary 20 ft to 30, or even 40 ft. This eliminates one-half to two-thirds the number of columns in a building, thereby increasing useful space, decreasing cost of foundations and columns and giving the architect much added freedom in room layouts. With this method of design it will also be found that the reinforcing steel will be at a safe distance from the bottom of the slabs so as to withstand the hazards of fire. The separation of the units of the slabs or beams can be accomplished simply by attaching vacuum holders to each half of the specimen. These holders are so designed as to transmit the needed horizontal pressure to corrugations in the slabs. Uplift is prevented by vacuum holding to slabs below. Hydraulic jacks can be inserted over the division plate and these jacks will then work against the ends of the vacuum holders. Specimens, such as most floor slabs of any width, can be prestressed

in this manner. This method, however, cannot be used for elements which are designed for extra heavy loads, such as bridge slabs. In such cases the method shown in Fig. 8 is simple to apply. This consists of laying the slab on temporary supports and anchoring one-half at the center to a "dead man." Heavy steel beams are clamped to the two adjacent ends of the two parts of the specimen.

When the beam is laid on temporary supports it is in effect unreinforced, because the steel wires are coated with asphalt. The method shown illustrates how one-half of the beam is bent up until the resulting wedge-shaped opening at the bottom equals t. In this bending, the steel flanges at the top, pressing against each other, prevent crushing of the concrete. When the beam has been bent up the required distance, a steel bar having a width t is inserted between the flanges of the beams under the slabs. The bent-up portion of the beam is then pulled down again to horizontal position. This leaves a rectangular opening between the two beams equal to t. This opening is then grouted, as described above, and the steel beams or plates are released after the grout has hardened. When bending up the beam, special precautions must be taken. It cannot be done by pulling up the end because, being in effect unreinforced before it is prestressed, it will break. For this purpose a vacuum concrete lifter is placed on top of the beam. This lifter serves two purposes in this case: (1) uniform grabbing, and (2) as temporary reinforcement, stiffening the beam while it is being lifted up. In pulling down the bent-up end to horizontal position, a vacuum lifter again serves in the capacity just described. In the case of a 30-ft bridge element 2 ft wide, the total force in the reinforcing steel was found to be 200,000 lb; t for a working stress $f_c = 110{,}000$ psi will be 1.6 in. The uplift in the arrangement shown is 10 tons. The anchorage at the center must, therefore, weigh at least 20 tons. In a factory the anchorage can be a long beam, which makes it possible to prestress many specimens simultaneously.

Cast-in-place prestressed concrete

Generally speaking, if the live load does not exceed 125 psf, and this includes most buildings, the separation of slabs to obtain the prestressing can be done by applying a vacuum holder to each half of the slab and then using hydraulic jacks between these holders for shoving the slabs apart (Fig. 9). These holders may have a lip which grabs the concrete slab at the point of separation to provide sufficient holding capacity. In the above example, with a column spacing of 40 x 40 ft, the prestressing would be done in two directions, that is, both transversely and longitudinally. The 40 x 40-ft slab would be cast in place but divided into quadrants. The number of columns would be reduced to approximately one-third as compared to ordinary reinforced concrete construction.

Precast long span floor slabs

In this case it is best to cast the individual slabs with a haunch at each end (Fig. 10). These slabs can be cast on a mold made of concrete in which

Fig. 8—Use of vacuum lifters in prestressing slab

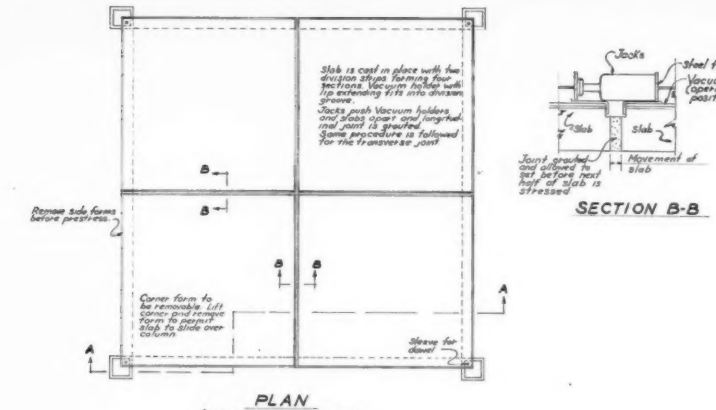

Slab is cast in place with two division strips forming four sections. Vacuum holder with lip extending fits into division groove.
Jacks push Vacuum holders and slabs apart and longitudinal joint is grouted. Same procedure is followed for the transverse joint
Remove side forms before prestress
Corner form to be removable. Lift corner and remove form to permit slab to slide over column
Sleeve for dowel
PLAN
(SLAB IN FINAL POSITION - REINF. NOT SHOWN)
Jacks
Steel frame
Vacuum holder (operating position)
Slab
Slab
Joint grouted and allowed to set before next half of slab is stressed
Movement of slab
SECTION B-B
Dowel Sleeve
Pressure grout after slab is pre-stressed
Grout packet
Formwork to suit
Hollow precast column
Fill with cure
SECTION A-A

Fig. 9—Arrangement for prestressing cast-in-place slabs

case they are lifted off the mold by the vacuum concrete lifter the day after they are cast. Another method is to cast them upside down as follows: Set edge forms on a concrete casting platform. These edge forms are held by atmospheric pressure, merely by turning a valve in a vacuum line. Then cast the slab to the required thickness, but without the haunches. Then set a vacuum form on the fresh concrete and vacuum process the slab itself. As soon as the vacuum is "turned on" this top form is held as in a vise. Then immediately pour the haunches and vacuum process them through the vacuum form. The vacuum form can be removed as soon as the concrete is self-supporting, or in approximately 20 minutes. Thus, the vacuum side forms and the vacuum processing forms can be re-used many times each day. The prestressed beams are laid up on temporary beam-supports between precast hollow columns. There are wide grouting joints between the slabs and short heavy bars are inserted near the top of the slabs in these grouting joints. These heavy bars are not prestressed, but they absorb a part of the tensile stresses of the negative bending moments, and in this manner the precast floor system can be designed as continuous beams over several supports. Grouting joints are also provided between the ends of the beams and all joints are grouted by the dry-pack method after the beams have been assembled between the columns. Reinforcing steel is placed in the inside of the hollow

columns, which are then filled with concrete in situ. This makes the entire assembly act as a monolithic structure. Fig. 11 shows this method of assembling floor slabs.

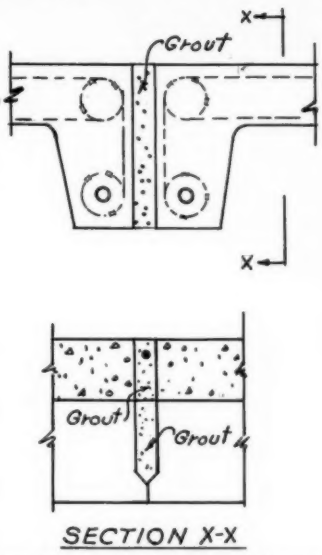


Fig. 10—Details of haunches and grouting of long precast slabs

Pipes and tanks

In the case of pipe or tanks, this method contemplates the use of three partition plates (Fig. 12). The three segments of the pipe are then pushed apart by internal pressure in a bag within the pipe. Water pressure is preferred to avoid any possibility of explosion. Only a small quantity of water is required if an outside bag, preferably made of rubber, is placed around an inside steel core, and water is injected between the bag and the core. In regard to pipe, there is an added advantage in that it is a one-operation process and all of the concrete in the pipe will always remain in compression. In most previously used methods, wire under tension is wrapped around a precast concrete shell and a ¾-in. covering of shotcrete is then sprayed on the reinforcement to prevent rusting of the steel. This outside layer adds extra weight to the pipe and is technically objectionable because it is not prestressed. Therefore, when the pipe is in use and is subject to internal pressure, fine cracks develop in the outside concrete layer making questionable the long-time protection of the steel.

ACKNOWLEDGMENTS

Thanks are due to A. S. Neiman for good suggestions, and to Professors Charles E. Schaffner, Sebastian Nardo and Burton Erickson for their assistance in measuring unit stresses.

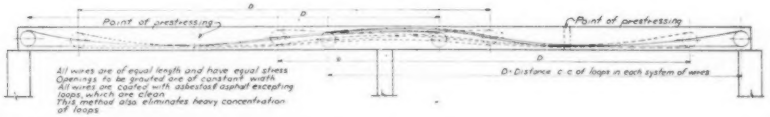
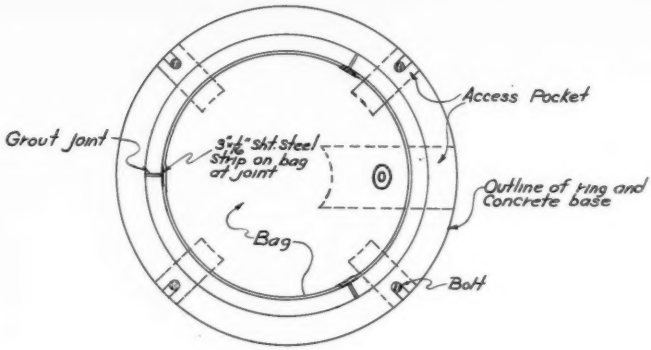

Point of prestressing
Point of prestressing
All wires are of equal length and have equal stress
Openings to be grouted are of constant width
All wires are coated with asbestos asphalt excepting loops, which are clean
This method also eliminates heavy concentration of loops
D=Distance c. c. of loops in each system of wires

Fig. 11—Application of looped prestressing rods to precast or cast-in-place beam or slab continuous over support



SECTION A-A

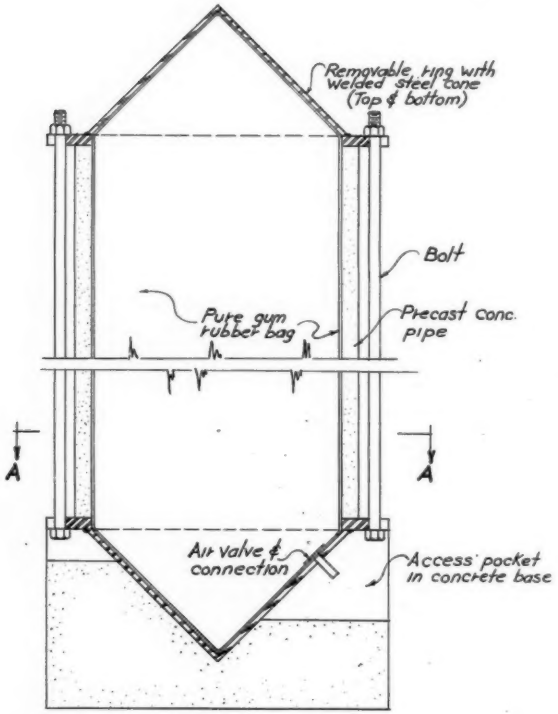


Fig. 12—Vacuum equipment for prestressing concrete pipe

Current Reviews*

of Significant Contributions in Foreign and Domestic Publications

Natural and artificial cooling of the concrete for a dam (in Japanese)

HIRONARU FUJITA, *Journal of the Japan Society of Civil Engineers* (Tokyo), V. 35, No. 6, June 1950, pp. 259-265

This paper describes the theoretical analysis and practical calculation of natural and artificial cooling for mass concrete and gives the plan and procedure for controlling the temperature of concrete in a dam.

Combined stresses in a continuous beam with a linear variable load (Trave continua inflessa e assialmente sollecitata da una forza variabile linearmente)

ANTONIO CATTIN, *Giornale Del Genio Civile* (Rome), V. 87, No. 9, Sept., 1949, pp. 458-465

Reviewed by GENNARO MIANULLI

The author arrives at an equation of three moments which has some analogy with the equation developed by Clapeyron.

Symposium on dynamic stress determinations

Special Technical Publication No. 104, American Society for Testing Materials, Philadelphia, 64-pp. $1.50

The four technical papers and discussions comprising this publication were presented at the first A.S.T.M. Pacific Area National Meeting, San Francisco, Oct., 1949. Investigation of dynamic conditions of materials and structures has become increasingly important. The purpose of the symposium was to present in a single source pertinent information on the scope, applicability, possibilities and limitations of electronic measuring and recording devices. This publication is therefore of interest to those who may have to undertake such tests or have to apply the results obtained.

Use of accelerators in the manufacture of concrete products (L'Emploi d'accelerateurs dans l'industrie des produits en beton manufacture)

MARCEL THUILLEAUX, *Revue des Materiaux*, No. 417, June 1950, pp. 212-16

Reviewed by PHILLIP L. MELVILLE

The uses and advantages of $CaCl_2$ in concrete are reviewed. Results of a number of tests in France and Belgium are reported. Methods of mixing are described with many references to U. S. practice.

Steel joists used for reconstruction of permanent small span reinforced concrete bridges (Utilizzazione di trave metalliche tipo "Flambo" residuate di guerra per ricostruzione di ponti permanenti in cemento armato)

GIUSEPPE RINALDI, *Giornale Del Genio Civile* (Rome), V. 87, No. 10, Oct. 1949, p. 513

Reviewed by GENNARO MIANULLI

Reconstruction of Pizzocalvo highway bridge, across the Idice River is described. The main reinforcement is a steel web joist of the "Flambo" type for girders supporting a slab.

Cement grouting

L. M. BAYLEY, *Commonwealth Engineer* (Melbourne), V. 37, No. 10, May 1, 1950, pp. 393-401

After emphasizing that the proof of all grouting work is negative since the lack of flow of ground water is the criterion of a job well done, a detailed description of drilling and grouting methods, mixtures and equipment is given. The necessary records and the use to which they are put are discussed. An appendix lists instructions to grout operators at the Warragamba Dam in New South Wales.

*A part of copyrighted JOURNAL OF THE AMERICAN CONCRETE INSTITUTE, V. 22, No. 2, Oct. 1950, *Proceedings* V. 47. Address 18263 W. McNichols Rd., Detroit 19, Mich. Copies of articles or books reviewed are **not** available through ACI. In most cases they can be obtained direct from the original publishers. Address, when available, will be furnished by ACI on request.

Prestressed concrete work in Great Britain

Chapter 14, June 1950, Cement and Concrete Assn., London

Reviewed by CHARLES C. ZOLLMAN

This information bulletin lists prestressed concrete work completed or in progress in Great Britain in Feb., 1950, which has been brought to the notice of the Prestressed Concrete Development Group.

Listed among others are a four-story block of lecture rooms for London University, a bus garage at Bournemouth with an unobstructed floor area 300 x 150 ft, 12 sill beams for jacking up bridges, 24 prestressed ground caissons for a deep water pier, prestressed collars for strengthening church tower at Silverdale, Staffs., and a prestressed locomotive turntable foundation, Manchester, Sheffield.

Design of reinforced concrete hyperboloidal tanks (Sul calcolo dei serbatoi iperboloidici in cemento armato)

ALDO FAVINI, *Giornale Del Genio Civile* (Rome), V. 87, No. 10, Oct. 1949, pp. 515-533

Reviewed by GENNARO MIANULLI

This is a study of reinforced concrete tanks with an unusual curved shape. The method of analysis follows in part the procedure used for thin wall slabs with a double curvature and is limited to slabs having flexural resistance. A different equation for elastic equilibrium is solved, using the approximate method employed by J. Geckler for spherical domes.

Investigation of load distribution between reinforced concrete floor slabs and their formwork

KNUD E. C. NIELSEN, *Bulletin* No. 19, 1949, Swedish Cement and Concrete Research Institute (Stockholm), 16 pp.

The object of this investigation was to study the loads to which the concrete floor slabs and their formwork in ordinary dwelling houses are subjected during construction. The deflections of the floor slabs were recorded both during the period of construction and after the completion of the house. The rate of construction and the quality of the concrete were taken into account, and a comparison was made between the structural actions of several types of floor slabs. Furthermore, a study was made of the influence exerted by swelling and shrinkage of form timber caused by variations in moisture content.

Recent research on vibration of fresh concrete (Recentes recherches sur la vibration du beton frais)

ROBERT L'HERMITE, *Cahiers du Centre Scientifique et Technique du Batiment* (Paris), First Quarter, No. 7, 1950

Reviewed by PHILLIP L. MELVILLE

Workability should be divided into several factors. One is the amount of work required to place the concrete. Another is its ability to resist segregation. The study of the latter is known as rheology and is evaluated with a device known as a regidometer. The device showed that friction in concrete disappeared with vibration. Experiments indicated that concrete is a hydrostatic medium. The vibrations were recorded electrically with a pressure cell of new design. The results are backed by a detailed theoretical analysis.

The construction of aircraft hangars in prestressed concrete at the Melsbroeck Airfield near Brussels

H. C. DUYSTER, *Bulletin* No. 12, Cement and Concrete Assn., London, Feb., 1950

Reviewed by CHARLES C. ZOLLMAN

The original Dutch paper by the same author, published in *De Ingenieur*, May 1949, was reviewed in detail in the ACI JOURNAL, Apr. 1950.

This unabridged translation is well presented and illustrated with photographs and sketches. It will be a valuable asset to any engineer interested in long span concrete structures.

Skin stresses developed in analyzing domes (Tensioni pellicollari nelle cupole di rotazione con forze distribuite superficialmente)

OSVALDO ZANABONI, *Giornale del Genio Civile* (Rome), V. 87, No. 9, Sept. 1949, pp. 442-457

Reviewed by GENNARO MIANULLI

It is generally known that action of the internal stresses in a dome are difficult to determine. The author attempts to overcome the uncertainties encountered in analyzing structures of this type by assuming a few simple principles from the theory of elasticity combined with the principle of De Saint Venant on the effect of redundant reactions applied at the edges of a curved slab which are practically nullified.

Skin stresses, as treated in this article, is a mathematical expression and may be defined as the internal stresses resulting from the computation of a curved slab when it is assumed that there is no flexural and torsional rigidity.

New means of measuring plasticity (Nouveau moyen de mesure de la plasticite)

R. M. Berthier, *Revue des Materiaux*, No. 417, June 1950, pp. 187-216

Reviewed by Phillip L. Melville

Plasticity in such media as clay, mortar and fresh concrete are measured with a new device. The apparatus consists of a cube hinged along verticals which may be deformed into a rhombohedron by applying a known load to two opposite vertical sides. The minimum load to cause deformation, load as a function of the deformation and the rate of deformation are measured. For a cube 10 cm on the side, a load of 40 kg gives deformations of from 1 to 10 cm. The results are reliable and are well correlated to slump and flow tests. The method could also be used on soils with good results.

The effect of calcium chloride on concrete (Le traitement de beton au chlorure de calcium)

M. Thuilleaux, *La Technique Moderne—Construction* (Paris), V. 5, No. 3, Mar.1950, pp. 79-82

Reviewed by Alexander M. Turitzin

In 1930, Prof. G. Magnel of the University of Ghent, Belgium, presented a paper to the Belgium Society of Testing Materials on the advantages derived from the addition of calcium chloride to concrete mixing water. Twenty years of continuous practice in Belgium did not, however, convince the French authorities of the merit of adding calcium chloride to concrete mixing water. As a result, French contractors and manufacturers of prefabricated concrete members are still ignorant of the practical service calcium chloride can render.

The author describes a series of tests performed on 10 year old treated concrete in France, Belgium and Sweden. He states that when a maximum of 2 percent by weight of the commercial calcium chloride (with respect to cement) was added to the concrete mixing water, no reduction in the ultimate compressive strength of concrete was experienced, no corrosion of the steel reinforcing was observed, and no additional efflorescence occurred. Additional shrinkage was observed, however, but all shrinkage was within permissible proportions. In dry atmosphere a reduction in shrinkage was found in concrete specimens containing calcium chloride.

One of the greatest advantages derived from the addition of calcium chloride is the reduction of the time necessary for curing and therefore the earlier availability of the forms for re-use. Another advantage is the protection of the fresh concrete against sudden frost.

The hardening process of lime mortar (Weisskalkmoertel)

K. Alberti, *Zement-Kalk-Gips*, V. 3, No. 2, Feb. 1950, pp. 25-30

Reviewed by Werner H. Gumpertz

The three theoretical explanations of the hardening of lime mortar are considered. The supporters of the first theory ascribe the hardening to the formation of calcium carbonate ($CaCO_3$) from calcium hydroxide [$Ca(OH)_2$]; the other chemical theory attributes the hardening to the reaction between the calcium hydroxide and the silica contained in the aggregate. The third theory states that hardening is due to evaporation of the water in the mix, producing crystallization, or that colloidal action causes capillary phenomena to harden the mix.

A testing setup for carbonation experiments is described which is suitable for testing the hardening and the ultimate strength of lime within a maximum of 21 days. The utility of the described apparatus in testing hydraulic limes is to be doubted. It can be assumed that the exclusive influence of the carbonic acid will retard or even stop the hardening of the silica. Further experiments in this direction will be required.

The conclusions reached from the experiments were (1) hardening cannot be attributed to the formation of lime silica through reaction between the lime hydrate and the silica in the aggregate, (2) about the effect of the silicate on the lime hydrate: the hardening of lime mortar is essentially a hardening of the carbonate, since compressive strength rises with the carbonation of the mortar (3) the setting of the lime mortar has no connection with the actual hardening. The reaction between lime hydrate and carbonic acid is of decisive importance for the hardening and strengthening of lime mortar and (4) the speed of reaction between lime hydrate and carbon dioxide is essentially dependent on the relative humidity of the surrounding air. The mortar strength depends primarily on the content of cementitious material and the porosity of the aggregate.

Lightweight concrete (Les betons legers)

R. DUTRON, *Annales de L'Institut Technique du Batiment et des Travaux Publics*, New Series, No. 138, Beton Arme, No. 13, June 1950

Reviewed by C. P. SIESS

Properties of lightweight concrete made with mineral aggregates are presented and discussed. Two types of lightweight concrete are considered: concrete made with lightweight aggregate normally graded so that all voids are filled with mortar, and concrete made with either lightweight or normal aggregates with "no fines" gradation so that a porous structure is created. Values of density, compressive strength, modulus of elasticity, coefficient of thermal conductivity and moisture absorption are tabulated for concretes of both types made with various aggregates and various mix proportions. Other properties including shrinkage, sound transmission, capillarity, rain penetration, durability, fire resistance, adhesion of plaster, nailability, and sawability are discussed in general terms.

Basic reinforced concrete design

G. E. LARGE, The Ronald Press Co., New York, N. Y., 334 pp., $5.50

Reviewed by PAUL ROGERS

This is an unusually well prepared and well edited textbook for undergraduate students. Since it is based in all practical matters on the latest (1947) ACI Building Code, it is probably the most up-to-date book on this subject.

The introduction helps the student to familiarize himself with concrete aggregates, the making of concrete, and the water-cement ratio. Modulus of elasticity is explained, and plastic flow is appraised. Logical instruction is given as to the role of reinforcing in columns and beams. The need for temperature reinforcing is emphasized. Reference is made to the new high-bond bars and the use of the ACI manual is recommended.

In later chapters the general treatise on reinforced concrete analysis is given. Separate chapters are devoted to the flexure of beams; bond and shear; columns; classical and modern analysis for continuity; building frames; two-way and flat-slab floors and footings. Short historical notes brief the development of concrete and pictures of outstanding concrete scientists are presented.

Probably the greatest asset of this book is the presentation of numerical problems with their complete solutions. All calculations are carried out in computation sheet form which will be helpful for the future designer. It is regrettable that the book does not deal with special problems, like torsional stresses, deflections, retaining walls, composite beams, etc.

It is believed that this book is a valuable addition to the concrete literature and is particularly useful as an introduction to the science of reinforced concrete.

The new prestressed concrete De Smet Bridge over the canal at Ghent, Belgium (Le nouveau pont en beton precontraint de la rue De Smet sur le Canal de Raccordement a Gand)

F. RIESSAUW, J. DOOMS; M. VAN CAUWENBERGE and D. VANDEPITTE, *Annales Des Travaux Publics De Belgique*, No. 6, Dec. 1949, pp. 687-716

Reviewed by CHARLES C. ZOLLMAN

In comparing in detail a structural steel rigid frame and an ordinary reinforced concrete rigid frame with a prestressed concrete girder design, all prepared for a 94 ft 6 in. span bridge, the authors bring out clearly that the prestressed design was the only practical and economical answer for this project.

Only a prestressed girder bridge with the total permissible depth of 3 ft 9 in., including road surfacing, would have, under full load, a deflection not exceeding ¾ in. A deflection of 2⅜ in. was anticipated for a steel girder design. (Steel trusses were not acceptable.) While foundation work was in progress it was possible to precast on the river bank the 35 girders required to form the 39-ft roadway. Falsework is eliminated and uninterrupted navigation, which was another requirement, was made possible.

The rigid frames produced large horizontal thrusts, requiring extensive and costly foundation and water work. The prestressed girders produce only vertical reactions, a more economical solution. As it was, the bids on the prestressed design based on the Magnel-Blaton sandwich plates were about 14 percent lower than those for the reinforced concrete rigid frame.

The authors discuss further the main design features, some of the computations prepared for the project, and comment extensively on the construction methods used, both for the substructure and superstructure.

Design of concrete structures

Second revised edition, Czechoslovakian Society for Regulations, Prague, Feb. 1950

Reviewed by IVAN M. VIEST

As was the 1931 edition, these new Czechoslovakian regulations for the design of concrete structures are based on the classical theory. However, a supplement was published simultaneously which allows, under certain conditions, design on the basis of an ultimate theory.

These regulations are divided into four chapters: I. Notation; II. General Rules; III. Statical Analysis; IV. Limitations. The methods of analysis and loading requirements are discussed in the third chapter which includes also some quality requirements for the materials, the allowable stresses, instructions for consideration of the external and internal forces and stresses, and instructions for the computation of deformations.

The principal changes from the old regulations are (1) The new regulations are not intended for bridges and for precast structures; (2) The concrete quality for the structural design considerations is based solely on the ultimate compressive strength of 20-cm cubes, it is independent of the consistency of the mix; (3) Provisions are included for the use of twisted and deformed bars.

Reinforced concrete design, Supplement

Czechoslovakian Society for Regulations, Prague, Feb. 1950

Reviewed by IVAN M. VIEST

This supplement to the regulations for the design of concrete structures introduces the ultimate design of reinforced concrete structural elements for the first time as an officially recognized method in Czechoslovakia. This method is optional and it may be used only with the consent of the owner. Especially careful workmanship and thorough control of the concreting operations are required on the job.

The regulations prescribe the following basic assumptions for computation of the ultimate capacity of reinforced concrete elements: (1) At the ultimate load the stress in the reinforcing bars is equal to the specified yield point value and the stress in the extreme compressed fibers of concrete is equal to the specified ultimate value; (2) When the element is subject to bending, the distribution of the compressive stress in concrete at the ultimate load is assumed to be similar to a cubic parabola; (3) The concrete is assumed not to take any tension. Concentric compression (including both tied and spiral columns), combination of compression and flexure, simple tension, combination of tension and flexure, and flexure are discussed. Buckling, diagonal tension, bond, torsion, and confined compression are also considered.

Factors of safety against failure are listed; they vary from 1.65 to 2.5 with the type of loading, type of structural element, and type of stress condition.

The designer has a choice between concretes of three qualities. The regulations specify the ultimate design values of various types of stress. The minimum compressive strength of 20-cm cubes is the criterion of the quality of concrete. Minimum and maximum limits are given for the percentage of reinforcement.

These regulations are considered as tentative. It is anticipated that the ultimate theory will be incorporated in the regulations "Design of Concrete Structures" after some experience with its use.

Dynamic testing of concrete (L'Auscultation dynamique du beton)

J. CHEFDEVILLE and G. DAWANCE, *Annales de L'Institut Technique du Batiment et des Travaux Publics*, Essais et Mesures No. 16, No. 140, New Series, July-Aug. 1950

Reviewed by C. P. SIESS

Four devices for the dynamic determination of the modulus of elasticity of concrete are described. Two are of the resonant type utilizing, however, longitudinal vibrations, while the other two measure the speed of sound through the concrete, and appear to be similar in many respects to the apparatus developed by Leslie and Cheesman (ACI JOURNAL, Sept., 1949). The principles and uses of the devices are (1) Resonant type, using loud speaker as driver and electromagnetic pick up. Used with prismatic specimens 7 x 7 x 28 or 7 x 7 x 40 cm. Vibrations excited longitudinally with speaker at one end and pick-up at the other. (2) Resonant type, with longitudinal vibrations excited by blows of small electromagnetically operated hammer and picked up by quartz crystal. Used for specimens 31.3 x

31.3 x 100 mm with frequencies in the range 8000 to 23,000 cps. (3) Speed of sound measured between two points on opposite faces of small specimens (less than 40 cm thick). Emitter and receiver both quartz crystals. Radar type pulse system used and time of transit measured by crystal generated electronic time scale and delay circuits. (4) Excitation by small cam-operated hammer at frequency of about 5 per second. Hammer blow applied at surface but in direction parallel to surface, and timing picked up by electromagnetic device attached to hammer. Impulse received by magnetostrictive pickup located on same face of structure at known distance from hammer. Time measurement by radar-type circuits. Application limited to distances of 0.3 to 2 m.

Results obtained with the various types of apparatus are compared and some applications to the study of properties of concrete in the laboratory and in the field are given. These included studies of the influence of the manner of curing on the modulus of elasticity; the variation of modulus with time, starting in one case with fresh neat cement paste and observing it during the hardening period; prediction of concrete modulus from the known moduli of the constituents; and the relation between modulus and compressive strength of cubes. Field tests on the Plougastel bridge are mentioned.

Prestressed concrete—Various systems of prestressing (Le beton precontraint—Procedes)

V. Weinberg, *La Technique Moderne—Construction* (Paris), V. 5, No. 6, June 1950, pp. 176-179
Reviewed by Alexander M. Turitzin

The author, a prominent concrete expert and a holder of a French patent on prestressed concrete, classifies the various existing systems of prestressing into three groups, according to the way the compression is transmitted to the concrete by the prestressing forces. In the first group, the concrete is put under compression by means of high-strength wires tensioned by jacks applied against the ends of the concrete member, after the concrete has hardened. To avoid bonding of the concrete to the steel, the wires are either wrapped in paraffined paper or thin steel sheeting, painted with asphalt, or placed into longitudinal holes provided for that purpose in the concrete member. The method of anchoring the ends of the stressed wires accounts for the difference between Freyssinet's method which uses a conical anchorage, and Magnel's method which uses a sandwich-plate anchorage.

In the second group, compression is transmitted to the concrete by bond, by means of wires under tension placed in the forms before the concrete is poured. In this method of prestress, the wires are threaded through the forms, the tension is applied by jacking against anchors located outside the forms, and, after the concrete has hardened, the wires are cut away from the jacks. The tension in the wires is counteracted by the concrete to which an initial compression is transmitted by the bond between the concrete and the steel. This method of prestress initiated by Freyssinet was perfected by Hoyer in Germany.

In the third group, compression is transmitted to the concrete by high-strength wires tensioned before the concrete is placed in the forms. Anchorages are placed at the ends of these wires and compression is transmitted to the concrete by the internal anchorage as well as by the bond.

The author, in collaboration with M. Vallette has patented a system in which steel pipes and pins serve the role of internal anchorages. The last part of the article is devoted to the description of a prestressed system developed by M. Vallette who considers a reinforced concrete beam a tied arch. The steel tie is tensioned by loading the arch. After the desired tensile stress is obtained in the tie, the space between the intrados and the tie is completely filled with concrete. Compression in the concrete is produced by removing the external load after the concrete has set.

Flat slabs and methods of design (Solai a fungo—Norme di calcolo e applicazioni)

Ettore Gallareto, *Giornale Del Genio Civile* (Rome), V. 87, No. 10, Oct. 1949, pp. 503-512
Reviewed by Gennaro Mianulli

The Italian Building Code has made no provisions for flat slab construction. Designers must refer either to American or German regulations and experiences.

The author, in this article, discusses analytical assumptions made by Grashof, Marcus, Hager, Lowe, Mayer, Doeink, Westergaard, Slater, Eddy and others in America and

Europe. Moment coefficients of various authorities and building codes are tabulated, results compared and reinforcement rules are pointed out for each case. This investigation was undertaken prior to the design and erection of a three-story flat slab building 44 m wide and 123.65 m long, on pile foundation and located on the waterfront of Savona, for the Societa' Chini of Milan.

The ACI regulations were employed for computing the stresses, as the formulas and rules are derived from information gained by tests made on actual structures in complete buildings.

Measurement of the forces, and their variation, in accessible wires in prestressed concrete structures as applied to the Sclayn Bridge. Mesure des efforts et de leur variation dans les fils accessibles des ouvrages en beton precontraint—Application au Pont de Sclayn)

E. Dehan and H. Louis, *Annales de Travaux Publics de Belgique*, No. 2, Apr. 1950, pp. 201-256
Reviewed by Charles C. Zollman

The continuous prestressed concrete bridge at Sclayn, Belgium, has been provided with 4 additional unbonded Blaton-Magnel wire units in order to investigate concrete and steel lossed and to study thereby the behavior *in time* of prestressed concrete bridges in service.

This long-time investigation will cover (a) measurements of the total force, and its variation, of a wire unit made up of several wires (8 and 16 wires), (b) measurements of the force, and its variation, of the individual wires and (c) measurement of the deformation of the wires.

In this first introductory paper, the sensitive instruments to be used and the methods of measurement which have been acceptêd are described and discussed in detail. Where necessary the authors elaborate on the theory whereon their measurements will be based.

The authors further elaborate on some measurements made prior to Nov. 15, 1949. These refer mainly to the deformation of the bridge, as vertical movements and rotations of both spans were observed and recorded during the stressing of the wires which produced the horizontal force of 6600 U. S. tons.

A complete report and the interpretation of the measurements will be made available to the engineering profession at a later date. The entire investigation program is made under the auspices of the Department of Public Works of Belgium.

Those in the engineering profession who are concerned with research and testing of concrete will find this article a valuable asset in their work.

The Sclayn Bridge over the Meuse (Le pont du Sclayn sur la Meuse)

Erwin Storrer, *Annales des Travaux Publics de Belgique*, Apr. 1950, No. 2, pp. 180-196
Reviewed by Charles C. Zollman

The author, Chief Engineer and Director of the Department of Public Works of Belgium, reviews in the introduction of this first paper of a series, the history of the previous two Sclayn bridges, which were each destroyed by war. For the third Sclayn bridge, the author continues, the Department prepared plans in 1947 for a steel truss of the bowstring type. However, specifications permitted contractors to submit bids based on their own designs.

Eight bids were submitted for the Department's design, 11 for several reinforced concrete designs prepared by bidders and 3 for prestressed concrete designs, also prepared by bidders. The award was finally made to Enterprises Blaton-Aubert for their prestressed box-girder design based on the Blaton-Magnel sandwich plate. Of the 22 bids, this bid was second low, but it met all of the Department's requirements, including the severe criteria set for a prestressed design. Some of these criteria are of great interest and may serve as a basis for other work. They are:

1. Final computations submitted were to be made for the variable dead load due to the variable depth of the girder and with variable moments of inertia. Allowance had to be made for shrinkage and plastic flow of concrete and creep of steel. The forces and deformations, which it was anticipated would occur during the various phases of construction, were to be investigated.
2. The allowable compressive stress was not to exceed 2200 psi.
3. The allowable tensile stress was not to exceed 220 psi. If, however, the stress were to exceed this value, the tensile stress would have to be taken in its

entirety by ordinary reinforcing steel. For regions of the girder where computations were to be uncertain, the allowable tensile stress was to be reasonably reduced.

4. The allowable tensile stress in the wires was not to exceed 120,000 psi. The run of the stressing jack was to be large enough to permit the stressing of the pair of wires in one single operation.
5. Prestress losses due to shrinkage and plastic flow of concrete, and creep of steel wire were assumed to be 15 percent.
6. To insure a gradual distribution of the concentrated loads at the bearing plates, a careful analysis for the end blocks was to be made.
   Further, the wires were to be grouted at their ends for at least 10 ft to insure transfer of the load to the concrete by bond.
7. Transverse stiffeners were to be provided. Their dimensions had to be such as to distribute the live loads between the walls of the box girder.
8. An absolute requirement was to solidarize the slab, walls and stiffeners, by means of ordinary reinforcing steel, and the provision of haunches where necessary.
9. The wire units were to be so placed inside the box girders that they would follow the deformations of the girder due to deflections without modifying their eccentricities. The spacing of the supports of the wire units in the central part of the girder were not to exceed 15 ft.

In the technical description of the bridge that follows, the author brings out, point by point and in detail, how the cited requirements were met. Plans and details are included, many illustrated by good photographs.

European concrete practice

The Reinforced Concrete Review, V. II, No. 1, Jan. 1950, The Reinforced Concrete Assn., London
Reviewed by C. P. Siess

This issue contains several brief illustrated articles describing: (1) The construction of a deep water quay using reinforced concrete caissons cast on shipways and floated into position and sunk. (2) The use of prestressed and precast members in the beam-and-girder floor of a warehouse. (3) The design of a concert hall incorporating several interesting features to prevent sound transmission through the frame, and an unsuual type of balcony framing.

Abstracts of two lectures on prestressed concrete by Prof. G. Magnel and M. Freyssinet are presented at length, several pages being devoted to each.

An original paper by Dr. A. R. Collins entitled "The Principles of Making High-Strength Concrete" discusses the design and properties of concretes having strengths greater than about 5000 psi, as might be required for use in prestressed concrete.

Another paper, "Translucent Concrete" by H. Wingrave Newell, discusses and illustrates a type of construction common in Europe consisting "... essentially of reinforced concrete slabs, grids and arches in which glass lenses are inserted." Only cases in which the glass inserts participate in carrying the load are considered.